ELECTRICAL ENGINEERING

JULY 1943

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The Cover: Sighting of this three-inch antiaircraft gun of the 62d Coast Artillery defending New York against a simulated night air raid is done automatically, accurately, and instantly by an electrical control system

Official Signal Corps Photo

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VOLUME 62
NUMBER 7

Statements and opinions given in articles and papers appearing in *Electrical Engineering* are the expressions of contributors, for which the Institute assumes no responsibility. ¶ Correspondence is invited on all controversial matters.

Published Monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

HAROLD S. OSBORNE, President
H. H. HENLINE, National Secretary

PUBLICATION COMMITTEE: Howard S. Phelps, *chairman;* C. E. Dean; F. Malcolm Farmer; H. H. Henline; K. B. McEachron; John Mills; A. G. Oehler; P. H. Pumphrey; H. H. Race; S. B. Williams

Electrical Engineering: Copyright 1943 by the American Institute of Electrical Engineers; printed in the United States of America; indexed annually by the AIEE, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index;* abstracted monthly by *Science Abstracts* (London). Address changes must be received at AIEE headquarters, 33 West 39th Street, New York, N. Y., by the 15th of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge.

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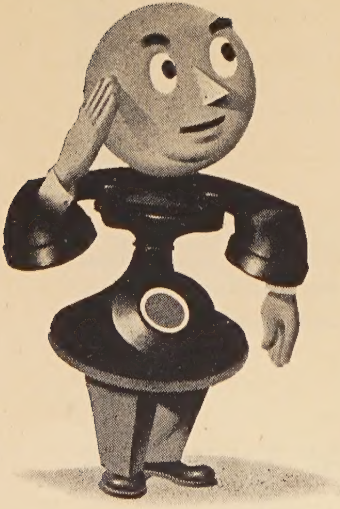

A Flag with 46,200 Stars

The service flag of the Bell System had 46,200 stars on May 1. It has a lot more now. Telephone men and women are serving with the armed forces everywhere.

Those who are right in the middle of the fighting realize especially the importance of the telephone job back home.

"Tell the gang," their letters say, "to keep on plugging.

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"Takes team-work to win a war — especially a big one like this."

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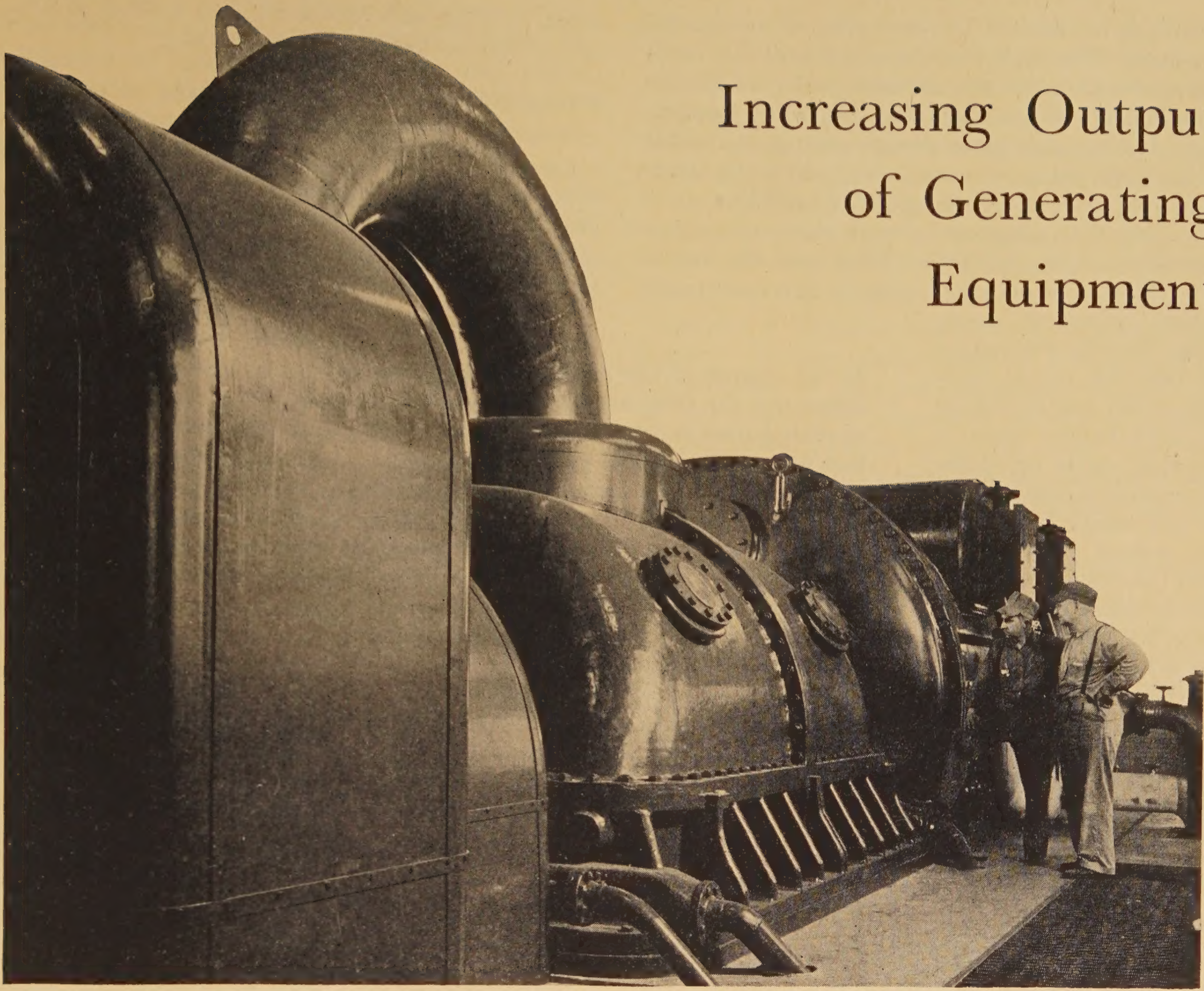
Increasing Output of Generating Equipment



MOST systems are faced with the same general types of wartime problems. Many are attacking them in much the same manner. However, it is believed that the following compilation and discussion of various methods and practices being followed in meeting wartime problems, description of particularly novel or ingenious practices and methods, determination of practices being followed most widely, and more detailed consideration of particularly pertinent subjects such as loading of generators will be a useful contribution to the war effort. This approach allows a pooling of ideas which the industry as a whole can draw upon and check against in its efforts to increase output of present generating systems.

There appears to be a worth-while reservoir of generating capacity for emergency use that still can be tapped in many cases by:

1. Reducing reserve capacity.
2. Adopting short-time loadings for generators and prime movers to replace normal reserves.
3. Loading each individual machine to its maximum safe continuous capacity as determined by allowable generator temperature or other limiting feature.
4. Studying all electrical and mechanical features of plants to eliminate existing bottlenecks to increased capacity.
5. Reviewing of interconnection facilities and contracts to eliminate features that limit maximum benefits.
6. Permitting a justifiable reduction in service reliability.
7. Allowing frequency to drift downward a fraction of a cycle or voltage to be lowered if total capacity is not quite adequate for an emergency at time of peak load.
8. Increasing pressure in hydrogen-cooled generators.
9. Operating generators at higher than rated voltage if power factor of load is higher than rated.
10. Taking full advantage of class-B insulation where it is now operated with class-A temperature rise.

Manufacturers' and Operators' Responsibility. Some suggestions made in this report* involve operation under conditions not covered by name plate or specification condition. The usual conception of a generator name plate is to identify the machine with respect to manufacturer and to indicate basic rating as fixed by specification. It does not guarantee that the generator is capable of safe operation up to temperature limits set by standards, irrespective of all other operating conditions.

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* The Interim Report on Emergency Measures to Increase Output of Generating Equipment and Systems, sponsored by the AIEE power generation committee (A. C. Monteith, *chairman* 1942–43), was presented at the AIEE national technical meetings in New York, N. Y., January 25–29, 1943, and in Cleveland, Ohio, June 21–25, 1943; at the AIEE South West District technical meeting in Kansas City, Mo., April 28–30, 1943; and before the electrical equipment committee of the Edison Electric Institute. Copies of the complete report (43-93-ACO) are available at AIEE headquarters at 65 cents each.

In order to be safe, some operators always stay within name-plate rating. It is believed that those who wish to get a little more out of a particular generator under specific operating conditions, either for the purpose of conserving critical materials to help win the war, or in more normal times to get more output per dollar of generator investment, will be well repaid for studying the general problem and their particular generators and for taking responsibility as to how these generators are to be operated.

At the request of the AIEE standards committee that the technical committees prepare wartime guides to help the electrical industry find ways and means of getting more out of what it has, two subcommittees of the AIEE committee on power generation have made surveys of what has been done by manufacturers and operating companies to increase the output of generating equipment and systems. This article outlines the results of the work of these two subcommittees; it comprises the "Summary" of the complete report.[†] Like other guides in this series, this report is intended to be educational and in no way mandatory. At the end of the war emergency, these guides will be reconsidered, and either approved, revised for normal use, or rescinded.

While a name plate does not signify more than specified characteristics, it should be recognized that manufacturers must have some guide in designing a generator which will indicate probable conditions under which the generator will operate. Therefore, the manufacturer's desire to stay within name-plate rating should be appreciated as the only criterion of operation available on which to base the design.

In investigating occasional cases of generator failure, it is interesting to note that nearly every failure brings out some new point with regard to generator design and operation. The design engineers are specialists. If generators are to be operated above name-plate rating under specific conditions without damaging them unduly or aging their insulation, the designers' co-operation in fixing limits will minimize the responsibility taken by operators when operating at other than name-plate rating. The manufacturers have stated their willingness to consult with operators and give them their best judgment for particular machines in question. In presenting the manufacturers' material in this report, they have picked case examples to indicate possible gains by different methods of operating machines, not with the idea that specific figures in the report will be used to operate any machine, but rather to indicate what might be obtained from the different factors. They feel that each machine should be treated as a special case.

Loading machines beyond name-plate rating will decrease the life of the insulation. It appears desirable that various economic consequences should be recognized, including such considerations as winding replacements, depreciation reserves, and the like.

EMERGENCY MEASURES TO INCREASE OUTPUT OF GENERATING EQUIPMENT*

Large generating equipment is normally designed and built to meet definite ratings and performance requirements as covered by mutually agreed on purchasing specifications or contract conditions. Most modern large generating units have class-*B* insulation for both stator and rotor windings. Large water-wheel generators synchronous condensers, and frequency-changer sets usually have class-*A* temperature-rise guarantees and class-*B* windings. Turbine generators which inherently are restricted in rotor ampere-turn output have class-*B* temperature-rise guarantees for rotor windings and class-*A* guarantees for stator windings. It is obvious that past and present purchasing practice has been to obtain generating units of great reliability and long life. The name-plate rating of the generator unit is usually the contract rating or an adjusted rating determined from tests at the factory or in the field.

Normal life expectancy of specific generating unit must be considered as depending upon load carried, load cycle, and quality of maintenance provided. Any contemplated increase in generator output above its contract rating necessitates full realization that there is an unknown reduction in life of the windings at the higher rating.

In considering increased output the owner or user of a generating unit is faced with two somewhat conflicting points of view. The manufacturer's responsibility during the guarantee period is definitely associated with the contract or name-plate rating and the performance guarantee. After expiration of the guarantee period the unit is unquestionably the customer's property to be used as conditions warrant. From the user's point of view, it may be considered sound practice to operate the unit (*a*) up to its contract value of temperature guarantees, or (*b*) up to the temperature limit of insulation used and as recognized by the AIEE and ASA standards. These principles must be extended to include all items of the machine affected by temperature in addition to the field and stator windings.

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* This section of the report was prepared by the subcommittee on emergency measures to increase output of generating equipment: C. M. Laffoon, *chairman;* S. H. Mortensen, Robert Treat.

[†] See footnote on preceding page.

Increasing Generator Output by Changing Generator Voltage. Some additional output can be obtained by taking advantage of the temperature margin that may exist in specific units. This may necessitate small changes in generated voltage and operation of each unit at the power factor most favorable for increased output.

A reasonable increase in generator voltage can be obtained without any increase in over-all flux of the unit by operating at higher power factors, which makes possible an increased output without increasing the stator current and without increasing appreciably iron losses under the higher load conditions.

Generators With Class-B Insulation and Class-A Temperature Guarantees. A machine with class-*B* insulation and class-*A* temperature guarantees can be operated continuously at loads which result in recognized class-*B* temperatures, provided its other characteristics are satisfactory at the increased rating. For machines of this class approximately 15 per cent increase in rating can be obtained with a reduction in life expectancy corresponding to the higher temperature.

Operation of Generators at Increased Output for Short Periods. Increased generator output at temperatures in excess of temperature limits recognized for the class of insulation and its application results in an appreciable decrease in life expectancy of the windings. This method of obtaining additional output for continuous or short-time loadings, with its resultant decrease in life expectancy of the insulation, may be justified economically under specific conditions.

In water-wheel generators and smaller turbine generators, field coils are comparatively free to move with change in temperature. While field insulation has to withstand a much lower voltage than armature windings, field windings are subjected to centrifugal forces, resulting from rotation, which put mechanical stresses on the insulating materials.

In large turbine-generator rotors, expansion and contraction are at least as important as total hot-spot temperature in determining insulation aging. A considerable part of the embedded length of the field copper may be considered as clamped to the wedges because of extremely high radial forces due to centrifugal loading. If the field windings are heated sufficiently while in this clamped condition, the conductor may be deformed plastically. A number of heating and cooling cycles may cause shrinkage of the rotor coils to the point where insulation failure may occur. Failures of this type are a function of temperature of the rotor as it comes up to speed, maximum temperature reached, and number of heating and cooling cycles to which the rotor is subjected.

In the stator winding, differential expansion results in relative movement between the outside of the insulation and the stator teeth, or it may cause internal slippage of the insulating material with the outside of the insulating wrapper more or less fixed with respect to the laminations. Since the end portions of the stator coils are anchored to fixed supports, expansion and contraction effects may result in either buckling or cracking the insulation.

Operation at Constant Temperature. Increased output can be and in some cases is being obtained by taking advantage of low ambient temperatures of the cooling medium. Although specification values of total temperatures are not exceeded, the life expectancy is decreased because of increased differential expansion and contraction of the winding copper and the surrounding iron.

Operation of Hydrogen-Cooled Generators at Increased Gas Pressures. In most cases, output of hydrogen-cooled generators can be increased approximately 15 per cent by increasing average pressures of the cooling gas from one-half pound gauge to 15 pounds gauge. Such increase in gas pressures may require changes in auxiliary equipment for supplying oil to shaft gland seals and for operation of the gas control.

Operating Practice for Reducing Hazards When Operating at Increased Ratings. Injurious effects of expansion and contraction due to starting and stopping conditions can be reduced by keeping the machine relatively hot during the shutdown period or preheating the field winding prior to starting. This can be accomplished by use of space heaters or by shutting off the cooling water to the gas coolers as soon as load is removed from the machine. Some improvement in life can also be obtained by regulating the flow of cooling water so that differential expansion can be kept more nearly constant for different ambient-temperature conditions. Increased loading of generators increases the desirability of careful inspection of both rotor and stator windings for evidence of distortion, cracks, and other forms of deterioration. Special precautions should be taken to keep the windings clean, loads balanced, temperature-indicating instruments checked, and readings taken on all detectors.

General Conditions. Since so many factors are involved in determining the available increase in output of large generating equipment, and any increase in loading must be checked carefully in relation to other associated main equipment, auxiliary apparatus, and the distribution system with its connected load, it is recommended that each case be checked with the respective suppliers. After obtaining and reviewing all essential data, the user and supplier should agree mutually on the rating capabilities of each particular unit, with full realization that the increase in output will result in a shorter life expectancy, and affect other important characteristics of the unit.

EMERGENCY MEASURES TO INCREASE OUTPUT OF GENERATING SYSTEMS*

Loading Generators by Temperature. There appears to be a general trend toward loading generators by temperature. Many systems report either that they have made temperature tests or calculations to determine how much their generator loads may exceed name-plate rating safely, or that they are operating according to temperature limits with temperature indicators for both stators and rotors instead of primarily by ammeter indications. The following conditions may permit continuous loading above name-plate rating:

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* This section of the report was prepared by the subcommittee on emergency measures to increase output of generating systems: R. P. Crippen, *chairman;* H. A. Dryar, A. J. Krupy, G. H. McDaniel, M. J. Steinberg.

1. Manufacturer's factor of safety larger than necessary to protect guarantees and meet operating contingencies such as load swings and small unbalance in phrase loading. This does not show in name-plate rating but may permit additional loading under proper conditions.

2. Load-carrying ability increased because ambient temperatures are less than specified maximum.

3. Kilowatt load capacity of generator increased because of power factor being higher than specified.

4. When adapting a standard design of generator to a specific operating condition, particularly in regard to power factor, it may be found that either raising or lowering terminal voltage may allow greater output in either kilowatts or kilovolt-amperes.

Additional factors which may permit loading above name-plate rating for short periods are:

1. When starting from light-load and low-temperature conditions, a generator can carry short-time loads in excess of normal capacity without exceeding normal temperatures, because it must absorb a considerable amount of heat before its temperature reaches a dangerous level.

2. In emergencies and for short-time peaks it may be more economical to operate a generator above its ordinary operating temperature, thereby incurring greater than normal rate of insulation aging for a short time, than to provide additional generating capacity for short-time loads.

Generators are important and costly machines; therefore due consideration should be given to a number of factors in arriving at maximum limits for either continuous or short-time operation above name-plate rating. The manufacturer's co-operation is desirable in studying individual generators for such operation. However, it seems desirable to suggest certain relatively conservative rules which it is believed will apply to most generators when loading them beyond their name-plate rating.

Rebuilding and Rehabilitation. Sometimes alterations can be made in generators on their auxiliary equipment to give added capacity. Cases have been found where recirculation of generator cooling air or water reduced capacity. One plant installed a cooling tower to reduce the high temperature of recirculated generator cooling water. In another instance increased capacity was obtained by installing a closed cooling system on a generator that had been discharging its ventilating air into the turbine room.

When it becomes necessary to reinsulate a generator, it may be advantageous to utilize a better grade of insulation to obtain greater capacity or longer insulation life. Where class-*A* insulation is replaced by class-*B* in a motor or generator, the capacity can be increased because of the increased permissible operating temperature. Also new insulation may require less space and therefore allow a larger copper cross section in the same slots.

Interconnected Operation. Principal benefits of interconnected operation have been arranged in accordance with the number of times the particular benefit was specifically mentioned in answers, as follows:

1. Continuity of service improved.
2. Maintenance schedule made more flexible.
3. Reduction in spinning reserve.
4. Diversity in loads of systems.
5. Replacement of high-cost steam energy.

Other benefits listed and finding appreciable support were:

6. Outlet for surplus hydroelectric energy.
7. Hydroelectric replacement transactions.
8. Higher load factor on efficient steam stations.
9. Reduction in fuel requirements.
10. Increased firm capacity of hydroelectric plants.

Interconnection may increase available capacity by decreasing spinning reserve requirements, by allowing steam plants to run at higher load factor with resultant storing of water at hydroelectric plants for carrying peak loads, and by whatever diversity there may be between the loads of interconnected systems.

Several systems with long interconnecting lines of 110 kv and 132 kv have had excellent results with automatic tie-line load-control equipment in decreasing magnitude of load swings on lines and thereby allowing increased loading without a corresponding increase in number of line tripouts because of steady-state stability limits being exceeded on load swings.

When systems are interconnected by relatively weak links, such as long single lines or frequency changers, application of automatic tie-line load-control equipment may result in a definite gain in transmission capacity.

Arrangements have been made in a number of instances for industrial customers having generating plants to operate in parallel and feed power back into the system, to carry their own load, or to carry reactive kilovolt-amperes. Other reported benefits from this type of operation are obtaining firm capacity, improved line regulation, improved service reliability in the immediate area, reduced peak demand, and reduced transmission losses.

Effect of System Voltage and Frequency on Load. Differences of opinion as to relative effectiveness of reduction in voltage as compared to reduction in frequency may very well be due to the different character of loads on different systems. Under proper conditions either or both methods may be effective in producing a certain percentage reduction in load.

With mixed types of loads it appears that total system load will usually be reduced by a slightly greater percentage than the percentage voltage reduction. Feeder voltage regulators must be made inoperative, or they will counteract the reduction in system voltage.

The consensus is that reduction of either voltage or frequency to reduce system loading is practicable only for short-time emergencies.

Magnitude of permissible voltage reduction is limited to a value below which there is possibility of damaging equipment or stalling motors. Outage of generating equipment on some systems has allowed system voltage to fall as low as 85 per cent over the peak load for several days in succession without any apparent damage to equipment.

A definite schedule of step-by-step load curtailment appears desirable to meet the exigencies of present operation, with reduced reserves and the possibility of bombing. Reduction of voltage or frequency may be considered as the first step in such a schedule. A good example is the following answer received:

> "Because of war hazards, we have a definite program of load curtailment in order to be prepared to hold on to our important military loads in case of loss of generating equipment or interconnection ties. We are able to make very definite curtailment in load by reduction of bus voltages by five per cent and by cutting back on feeder voltage regulators in substations a like amount. We are also able to get a considerable curtailment in load by cutting down the speed of street cars in the transportation system which we operate. These methods have actually been used in one case where we had a simultaneous outage of three major boiler units. Further methods of curtailment consist of actually getting customers to curtail their loads, and more drastic means in the nature of actual arbitrary circuit disconnections by the power company."

Power-Factor Correction. Power factor should be considered from the viewpoint of the whole system, beginning at customer's service switches and ending at the generating stations. Most companies attempt to generate reactive kilovolt-amperes in the reactive load area. To do this most effectively requires not only good system design but also good operation to keep power-factor correction in step with hour-to-hour changes in system reactive loading.

It is common practice to float hydroelectric generators on the line for power factor and voltage control. Good practice dictates that steam turbines shall not be loaded below certain values, generally in the neighborhood of 25 per cent of rating. Frequently this practice results in a decrease in over-all plant efficiency. One company reports that when turbine generators are floated on the line, cooling steam for the turbines is supplied from the main boilers through orificed by-passes around control valves. Another company is making tests on supplying cooling steam through by-passes around control valves but using steam at five pounds per square inch for station auxiliaries. A third company operates with the turbine blades in a vacuum.

Miscellaneous Methods of Releasing Capacity, Saving Losses, and Saving Critical Materials. Practice varies as to switching excess transformer capacity out of service during light-load periods. When both core losses and copper losses are considered, it does not appear that there will be ordinarily any advantage in switching transformers out of service if those remaining on the line will be loaded above name-plate rating.

Turning gears are used on a considerable number of large turbogenerators to equalize cooling of all parts of rotors and to allow machines to be brought up to speed and put on line more quickly than would be possible otherwise. Their performance appears to give general satisfaction. They are more important in reducing required spinning reserve on systems where steam generation is predominant than on systems with considerable hydroelectric generation, because on a hydroelectric system there is usually equipment which can be brought up to speed and put on the line in a very short time.

Daylight-saving time, 24-hour work by many industries, and dim-out regulation along the coasts have, in most cases, improved system load factor, thereby allowing greater kilowatt-hour generation without a corresponding increase in peak load. There may be some shifting of load to off-peak periods which can be effected if necessary, but many systems have daytime and nighttime peaks that are nearly equal. Shifting of load is more likely to be helpful on systems where steam generation is predominant and kilowatt-hour generation is usually limited by installed capacity than on systems where hydroelectric generation predominates, and total kilowatt-hour generation is limited by stream flow or pondage rather than by installed capacity.

Maintenance Schedules and Policies. Maintenance may be classified as breakdown, periodic, and preventive. Preventive maintenance is continually doing little critical maintenance jobs, in a scheduled and orderly manner, so that it is seldom necessary to do larger jobs. Generating units are generally in a good state of repair, because many companies, foreseeing that it would be difficult to do maintenance work when war loads became heavy, have done a more than normal amount of preventive maintenance in the last year or so.

The consensus is that load should not be curtailed unless it becomes necessary because of forced outage maintenance. There will apparently be no curtailment of load to meet schedules for preventive maintenance. Some answers indicate that maintenance schedules are made up a long time in advance and are adhered to very rigidly. One company stated that the preventive maintenance schedule was carried through at the expense of reducing operating reserves.

In most cases preventive maintenance schedules are not adhered to rigidly even though they were made up a year ahead of time. The period elapsing between scheduling of units has been lengthened in some cases, because of increased war loads.

Many companies have a rigid program of preventive maintenance and report that maintenance scheduling for a period of years has been adequate and therefore has left power-plant equipment in a good state of repair. Therefore, with increased loads that have been experienced in the past year and are expected to be experienced in the near future, it has been unnecessary to increase preventive maintenance. However, several companies are doing extensive preventive maintenance to conserve critical materials and thereby avoid major trouble.

The most frequent cause of delays in maintenance, except possibly load conditions, has been delays in deliveries of material. Turbines have been returned to service after removing rows of bad buckets, and other temporary repairs have been made to equipment while delivery of material was awaited for permanent repairs. Deferring maintenance until additional capacity is available is used as a factor in shaping maintenance schedules.

No mention is made of delays in maintenance because of lack of personnel.

Personnel Problems. The personnel problem is one of the most serious situations faced by operating utilities. Trained men have been drafted or have volunteered for the armed services or have left for jobs with higher rates of pay. New personnel is difficult to obtain and is often below the caliber of new personnel in more normal times.

There has been considerable discussion about use of women in operating and maintenance departments, and considerable interest has been shown in obtaining the general point of view in this matter.

Ten companies report use of women as clerks in plants. Drafting work, meter reading, and use of wives of patrolmen and operators as operators are each mentioned. The following positions are filled by women in some cases: meter tester, chemist, telephone operator, janitor, chauffeur, time keeper, mechanic for boiler repairs.

One station in England which uses a large proportion of women on their operation and maintenance staff, including switchboard operators, cites the fact that at the start of hostilities they anticipated that use of women would probably be necessary and started training them early. This suggests that, if it is going to be necessary eventually to use women in operating jobs of responsibility, it would be well to start training them now in minor jobs, so that they can be advanced if necessary.

There is no trend toward installation of automatic equipment for release of trained personnel for other duties. However, some companies indicate that they place great reliance on such equipment, and its use in other places may be worthy of consideration.

The Conservation of Materials

H. S. OSBORNE
PRESIDENT AIEE

The conservation of critical materials—necessary to the successful prosecution of the war effort—is a problem which engineers particularly can help to solve, since most critical materials are used in operations under the direction of engineers.

IT is appropriate that the Institute and the other engineering societies should have made the subject of conservation of materials an important part of their programs during the past year. It is, as Mister Nelson and other authorities have said repeatedly, a continuing and most pressing problem and, furthermore, a problem to the solution of which everyone can contribute directly and effectively. Furthermore, it is a problem which engineers particularly can help solve. Critical materials, those used, both for war production and for essential civilian purposes, are, broadly speaking, consumed by processes under the direction of engineers.

It is of some interest to note at the start that critical materials are scarce because of limitations in productive capacity and not from any scarcity in their occurrence in nature. Aluminum is as plentiful as water—this is literally true—it is simply not so available. Considering everything material which is available to man—the crust of the earth, the seas and the atmosphere—one half of the total is oxygen and one fourth is silicon. If these two of the 92 elements are deducted, of the 25 per cent which is left more than half is aluminum, iron, and magnesium.

This fact may have led some of us at the beginning of the war to have a false sense of security—to feel that we are the great producers of the world, and therefore, must have an overwhelming proportion of the world's productive capacity of scarce materials. This was true at the beginning of the war. However, the Axis greatly improved their position by their conquests in Western Europe, Russia, and the Far East. The latest figures

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Essential substance of an address delivered by President Osborne before many of the AIEE Sections during his term of office.

available, taking into account the effect of these conquests, show that the Axis then had 40 per cent of the world's productive capacity of iron and steel, 50 per cent of the capacity of aluminum and zinc, 60 per cent of the capacity of magnesium, 75 per cent of the tin, and 90 per cent of the rubber. This was, in part, offset by deficient capacities of some important things, particularly copper 20 per cent, and petroleum 7 per cent.

These figures are based on the latest data available, for the most part 1940 and 1941 and much has happened since then on both sides of the battle front. However, the figures are sufficient to make us realize that, by and large, we do not have an overwhelming superiority of productive capacity. In addition, the Axis has important resources not reflected in these figures. For years they had built up stock piles of the scarcest materials. Furthermore, they have systematically looted the occupied countries of the things which they needed, and these countries, of course, had vast quantities of metals and other materials in use for their ordinary domestic and industrial purposes. An Army authority remarked recently that so far the study of captured Axis war materials indicated they had not been obliged to make any compromise with quality for lack of raw materials.

Most of our scarcest materials are used for war purposes, and the armed forces are very alive to the problems of conservation. For example, the Ordnance Department of the Army has urged its manufacturers to make suggestions for changes in specifications or methods and has received thousands of suggestions which could be acted upon favorably. A recent letter from Major General Campbell, Chief of Ordnance, addressed to ordnance producers in American industry thanks them for their constructive suggestions of methods for increasing production; improving quality; and conserving materials, machines and man-hours; and closes with these emphatic words, "I cannot emphasize too strongly the fact that, unless means are devised to conserve critical materials, our production ceiling will soon be reached. This must not and will not happen. I know that I can count on you."

The tremendous results which have been obtained have been accomplished by literally thousands of changes. A broad consideration of the subject is best approached by the classification of these changes into different general methods of conservation.

Methods of Conserving Critical Materials

A. Making the greatest possible use of what we have:
  1. Increasing extent of use of existing facilities.
  2. Prolong life.
  3. Reuse of recovered materials.

B. Limiting of additions to and changes in facilities to those necessary for essential services. Similarly limiting production programs.

C. Making minimum use of critical materials in all construction and production:
  1. Substitution of less critical materials for more critical materials.
  2. Redesign to use less material.
  3. Limiting additions to facilities required for immediate needs only.
  4. Standardization.

D. Getting back into circulation materials which can be spared:
  1. Clean up and dispose of junk.
  2. Reduction of inventories.
  3. Taking materials out of working facilities.

Such a classification, similar to that which has been used by many of the Institute Sections in the consideration of this matter, accompanies this article. It is also similar to that used in a report prepared by the subcommittee on the conservation of materials published in the April 1943 issue of *Electrical Engineering*. That report gives various illustrations from within the electrical industries of the application of the different methods of conservation listed in the table.

The application of these methods of conservation involves a new approach on the part of engineers. Instead of projects being considered from the standpoint of economy of dollars, they must be considered from the standpoint of economy of materials; instead of projects being considered broadly from the standpoint of need or salability of services or products, consideration must be given to what is essential as a part of the war effort and to what can be done without.

Section A of the outline of methods refers to "Making the Greatest Possible Use of What We Have." This involves overloads of various types which normally would not be considered good engineering practice. It involves the use of maintenance and repair practices which normally would not be economical. It involves the development in many cases of improved methods of removal. For example, wire or cable which is to be reused must be taken down more carefully and by different methods than that which is to be junked.

Section B of the outline refers to "Limiting Additions to and Changes in Facilities to Those Necessary for Essential Services." This, of course, applies also to the production of products, as well as to the construction or modification of plant.

It is interesting to note, regarding the application of this method by public utilities, that under normal conditions they are under the legal obligation to give service to all comers without discrimination. This method of conservation involved discrimination between service demands which are considered essential and those which are not essential to the war effort. So the utilities needed help. They have received help in full measure in the form of numerous limitation orders of the War Production Board. As the utilities struggle with the headaches caused by these numerous orders, they will want always to bear in mind that the orders are a necessary part of the conservation program, enabling them to carry out a form of conservation which otherwise would be beyond their power.

Item C of the outline and its subdivisions cover a group of methods of conservation which touch the work of all engineers. Consider, for example, subitem C-1, "Substitution of Less Critical Materials for More Critical Materials." That in itself is a large subject and a romantic one. It is also one of constant activity because of the changing relative scarcity of various materials. The WPB endeavors to keep people up to date on this matter by the periodic issuance of a "Material Substitutes and Supply List," giving current information regarding the relative scarcity of materials. Some of the things in which electrical men are most interested have for a long time remained in the scarcest group and, in fact, are starred as "most critical" among those in the group. These include copper, aluminum, tin, and zinc. It is to be anticipated that they will remain in this group as long as an all-out war-production program is called for.

Substitution problems are reflected in war production, as well as in production of civilian goods. A large Government-owned airplane plant, requiring 21,000 fluorescent-light fixtures, pioneered in the use of painted masonite for the reflectors, instead of steel. Airplane designers have worked on means for using plywood instead of aluminum for the pilot's seat. An interesting example of the severe requirements in the design of war materials, however, is the fact that, while 200 pounds is considered sufficient to allow for the weight of the pilot, the seat must be designed to withstand eight times this weight because of the accelerations involved.

Subitem C-2, "Redesign to Use Less Material," also touches the work of every engineer.

The specifications for Liberty ships called for 25,000 feet of highly protected power cable per ship. Engineers found it possible by careful design to reduce this length 10 per cent. A large magnesium plant, recently completed, included several thousand tons of copper in the form of bus bars and heavy feeder cables. By careful design and by having parts cut exactly to length in the shop rather than fitted at the job, 400 tons of copper were saved in building this one plant. These are illustrations of one type of application of this method—attention to the details of design in structures or any assembly of materials.

Another use of this method is in the application of improved processes; for example, one munition manufacturer recently reported that by applying the method of powder metallurgy to the manufacture of one complicated part 650 tons of a scarce alloy were saved.

Sometimes conservation is brought about by the application of a radically new device or a system. There is a good illustration of this in the telephone field. For a long time the telephone companies have made use of what are called carrier systems, that is, systems by which several conversations can be carried simultaneously over the same wires. Previously these had been applicable only on open wires on poles. Shortly before the war the research program of the telephone companies produced an improved system by means of which 12 conversations could be carried simultaneously on two pairs of 19-gauge wire in cable. This great extension in the application of carrier systems for the production of long-distance telephone circuits resulted in tremendous economies in the use of copper in the construction of large numbers of additional long-distance circuits required because of the war emergency.

The third subitem, "Limiting Additions to Those Facilities Required for Immediate Needs Only," needs no elaboration; it is simply designing plant to meet current needs rather than designing it as normally would be the case, to provide for expected future needs over an economic period, which is often a considerable number of years.

The last subitem is headed, "Standardization." Standardization has long been an important activity in the electrical industries, and the AIEE has, from the beginning, been a leader in the standardizing movement. There is great activity now in all industries, at the request of the war authorities, in advancing war standards designed to conserve materials and man power. In this work the American Standards Association plays an important part.

An interesting specific illustration is the standardization of the parts of the radio sets for the Army and Navy. A number of committees is very actively advancing standards covering a wide range of types of parts, capacitors, crystals, dynamometers, insulating materials, resistors, potentiometers, and so forth.

The whole standardizing program is credited by the WPB with having effected large savings in materials. A recent statement claimed the saving to date of 60,000 tons of steel and 17,000 tons of copper.

The last group of items in section D of the outline, refers to "Getting Back Into Circulation Materials Which Can Be Spared." Eighteen months ago in many industries saving was the order of the day. The war clouds were black on the horizon, and, to prepare for the time when materials could not be had, procedures were set in motion to save many things which ordinarily would be junked. But this saving of materials was for an emergency, and the point is that this is the emergency. This is the time to use up what we have, to decrease inventories as rapidly as practicable, and to be sure that we are not saving materials which, either because of their physical condition, or because of the unlikelihood of their being used during the war, ought to be junked if order to put back into circulation the critical materials which they contain.

One recent incident illustrates very well the present point of view in Washington regarding the need for getting materials into circulation. For some time the Treasury has been providing silver for new Government plants, where large amounts of electric current are involved, to be used instead of copper in the building of new bus bars, feeder cables and heavy transformer windings. Between 15,000 and 20,000 tons of silver have been used in this way. The Institute was advised recently, however, that the Treasury had, in addition, about 16,000 tons of free silver not required for the construction of new Government plants which it was desired to put to work. The WPB obtained the approval of the Treasury to lend this silver to private industry to be placed in electrical installations as a substitute for existing copper in order that the existing copper thus released could be diverted to war purposes. This involves substituting silver for the copper now, replacing the copper and reclaiming the silver after the war, and guarding the silver for the duration of the war—expenses to be borne by the Treasury. The fact that this extreme move is being considered seriously is eloquent testimony of the need for additional copper. It is interesting to add that at the request of the WPB an AIEE committee was appointed to study with them the best means of making use of this silver in electrical installations, and the committee has made some constructive suggestions.

It has been pointed out that this problem of conservation is a problem for engineers. It is clear, however, that it is not a problem for engineers alone. It is a problem for everyone in the organization, particularly for every employee having to do with the use of materials. A part of the responsibility of the engineer, therefore, is to make sure that everyone in the organization realizes the importance of conservation and the methods of getting maximum results. A great deal has been done in training employees through articles in house organs, posters, exhibits, moving pictures, and so forth. There is no substitute in effectiveness, however, for a sustained showing of supervisory and managerial interest in the problem to insure that maximum results are obtained.

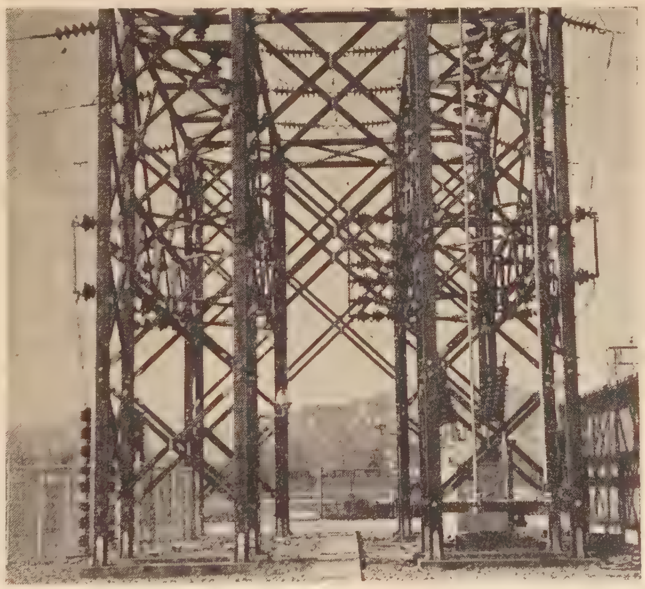
Conservation efforts are not limited to the employees of an organization. They apply also to the customers. Utilities—both power and communication—have long expressed this in their work with customers to help them to distribute the load and to avoid the use of unnecessary services. A great deal of help has been given by utilities to customers in the design of their own installations to use the minimum of materials.

For many organizations the biggest customer now is the armed forces. They, too, wish suggestions from suppliers as to methods of conservation, as the quotation from General Campbell's letter has already indicated.

One thing which is impressive in studying this matter is that small items should not be overlooked because they are small. For example, book matches are held together by a small staple of steel wire. It has recently been decided to shorten that wire one-quarter inch. By this means 100 tons of steel wire per year will be saved. As another illustration, it might be considered that it does not matter whether shoe eyelets are made of brass as they are so small. However, in 1941, 5,000 tons of brass were used for shoe eyelets.

Another point which strikes the student of this problem is the great effect of continued application to the problem. The results already achieved are certainly greater than any of us would have predicted a year or two ago. I do not think any utility man would have predicted then that in 18 months the use of copper by utilities could be reduced to ten per cent of its current rate without disrupting completely essential services, but this is what has been done in the past 18 months. While great progress has been made, it is evident that further progress must be made, since in many important ways the level of the war-production program is determined by the amounts of critical raw materials made available.

In conclusion, the problem of conservation of materials is a problem requiring the activity of all engineers and not something to be solved by groups of men in the armed forces and in the WPB. Beyond a certain point the conservation of materials requires a compromise between the saving of materials on the one hand and preserving the quality of essential services or products on the other hand. The problem is complicated and limited in extent of detail only by the detail of industrial and engineering processes. It is largely a technical problem and requires the application of the best technically trained brains in industry. We, who are associated with the electrical industry in various capacities, have the responsibility of using our imagination and our inventive genius in order to develop all the possibilities for conservation which there are and to keep those in authority completely informed so that the regulations of authority may at all times represent the best possible compromise in this difficult and essential matter.



Use of wood in place of steel in erecting this 110-kv substation structure on the system of the Public Service Company of Colorado saved 22,000 pounds of galvanized steel, and employed less labor which resulted in a saving of man power

Silver Anniversary of Symmetrical Components

In June 1918 Doctor C. L. Fortescue presented before the Institute the paper, "Method of Symmetrical Co-ordinates Applied to the Solution of Polyphase Networks." This paper has been recognized generally as having a far-reaching effect in the solution of unbalanced polyphase circuits. Since 25 years have now elapsed, the committee on power transmission and distribution believes that it is of interest and value to review the development and to consider the manner and extent of its effect on electrical engineering.

C. L. Fortescue

THE method of symmetrical components is basically a mathematical device for the practical solution of circuit problems. In many respects it bears the same relation to the solution of unbalance in polyphase a-c problems that the use of the complex number bears to the solution of single-phase and balanced polyphase problems. By the method of symmetrical components an unbalanced set of electrical quantities can be resolved into symmetrical systems of balanced quantities equal in number to the number of phases. Prior to the introduction of symmetrical components, the calculation of unbalanced networks was so laborious as to be impractical.

The title of Doctor Fortescue's paper included the term, "Symmetrical Co-ordinates." This term had its origin in the mathematical approach to the subject. Since then, however, the term symmetrical components, has come into general use, because it is more descriptive of the process to the engineer.

The beginning of the method of symmetrical components can be traced from concepts involving the use of positively and negatively rotating fields used in 1824 by Fresnel in connection with the study of polarized light and in 1892 by Ferraris and later by others in connection with the analysis of the single-phase induction motor. The concept of positively and negatively rotating fields was also used by E. F. W. Alexanderson in his phase balancer, which used an auxiliary machine, having a rotor that could be excited in the two axes, and a stator, connected for negative phase rotation, in series between the main machine and the system.

In 1912 L. G. Stokvis undertook the determination of the voltage regulation of the simple circuit consisting of a three-phase alternator subjected to unbalanced loads between line terminals. In solving this problem he used synchronous and inverse components which correspond in symmetrical components to the positive- and negative-sequence components. Stokvis did not have the concept of the zero-sequence component.

A method of resolving an arbitrary set of three vectors into residual, balanced three-phase, and single-phase components was developed by the California Joint Committee on Inductive Interference and used in their investigations as early as 1914. In this resolution the residual current is equal to three times the zero-sequence current of symmetrical components and, like the zero-sequence components, divides equally among the three phases. The single-phase current consists of a current flowing in a loop composed of two of the line wires.

The method of symmetrical components came to full fruition in the 1918 paper of Doctor Fortescue. In this paper the restrictions of previous work were surmounted, and a method of wide generality was developed, applicable to all kinds of circuit unbalances, to any num-

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Sponsored by the AIEE committee on power transmission and distribution, Philip Sporn, *chairman*. Prepared by general systems subcommittee, C. F. Wagner, *chairman;* J. W. Butler, S. B. Crary, J. E. Hobson, E. K. Huntington, A. A. Johnson, A. A. Kroneberg, M. C. Miller, H. K. Sels, H. M. Trueblood.

ber of phases, and to all types of circuit elements such as alternators (neglecting saliency effects), transmission lines, and transformers. Before Fortescue, the advance toward the ultimate development of symmetrical components, as we know it today, had occurred by isolated contributions such as those of Fresnel, Ferraris, Alexanderson, and Stokvis. Fortescue developed the fundamental relations concerning unsymmetrical systems, not only for the conventional three-phase system, but for the generalized *n*-phase system, and established the treatment on a sound and rigorous basis. The range of his method is well illustrated by the great simplification it effects in the treatment of polyphase circuits and machines, which have to be dealt with in the majority of electrical problems in the power industry. Under normal conditions the electrical quantities involved are very nearly symmetrical; that is, the impedances in the different phases are substantially equal, as are also the couplings between phases. A unique advantage of symmetrical components for networks of this character is the absence of interaction between the currents and voltages of the different sequences. This is the most important feature that differentiates Fortescue's method from that of his predecessors. Ordinary unbalances resulting from unbalanced short circuits can be represented by merely connecting the otherwise independent networks of the different sequences together in definite relations at the point or points of unbalance. This simplification assumes added significance, because the generated electromotive forces in normal machines (excluding certain types of phase balancers) are of positive sequence only.

Originally the greatest value of Fortescue's paper was generally thought to lie in the analysis of unbalanced conditions pertaining to rotating machines. Several years later the need arose for practical methods of calculating unbalanced system short circuits and analyzing system stability. The enormous simplification resulting from the application of the method to these purposes was pointed out in several papers and articles which served also to popularize the method. Since then the principal use of symmetrical components has been for the solution of system problems rather than for the analysis of isolated rotating machines.

In the 25 years that have elapsed since the introduction of symmetrical components, the method has gathered power with use until it has become an indispensable tool for the analysis of unbalanced circuits, under both steady-state and transient conditions. The method has come into use in a wide variety of practical applications in the electrical engineering field and has had an important part in the theoretical developments of many of these fields.

Symmetrical components provide a basic method for the calculation of power-system fault currents for circuit-breaker and relay applications. Calculations for the ordinary application of these devices were so difficult as to make them in many cases impractical prior to the introduction of symmetrical components. The development and use of meters, instruments, and relays responsive to the various sequence currents and voltages, individually or in combination, was a natural result of Fortescue's discovery.

System stability is of importance, especially under transient conditions that arise from system faults and normally involve some type of unbalance. Symmetrical components have greatly facilitated the calculation of transient stability.

The calculation of system faults by the method of symmetrical components necessitated the determination of the sequence-impedance characteristics of rotating machines and transformers. Unbalanced operation of machines also led to the analysis of the heating of synchronous and induction machines in terms of the sequence quantities. Likewise, in solving problems involving cables and aerial lines, the general use of symmetrical components has led to the modification of the tables of conductor data to include the constants for the different sequences.

In connection with the inductive co-ordination of power and communication systems, symmetrical components have become important to the communication engineer. This has resulted from the fact that low-frequency voltages induced in communication systems are determined largely by ground currents in adjacent power systems, which are calculated most easily by the method of symmetrical components. The sequence properties of power-system harmonics are also of interest to the communication engineer.

It is a curious circumstance that little application of the method should have been found in the railway field, the unbalanced problems of which caused the search for an ultimate discovery of the method of symmetrical components. The reason for this is that few railway developments have made use of polyphase motors supplied from single-phase systems or vice versa.

The proceedings of the electrical engineering societies show how profoundly symmetrical components have affected technical papers. After a lapse of a few years, most authors writing on fault-current calculations, relay applications, machine performance, and so on, began to use concepts based on symmetrical components. Today the method is so generally accepted that it constitutes part of the college curriculum for electrical engineering students. Textbooks devoted to the subject are available in all the principal languages.

The original paper on symmetrical components by Doctor Fortescue is now universally recognized as having provided a new method of great practical importance for circuit calculations. It has become a mathematical tool of great practical value to the power-system engineer. Presentation of the method of symmetrical components by Doctor Fortescue in 1918—25 years ago—was certainly a milestone in the progress of the electrical industry.

Special Metals in the Electrical Industry

FRANZ R. HENSEL JAMES W. WIGGS

Recent advancements and current trends in the development of metals and alloys used in various branches of the electrical industry are of particular interest in view of present-day increased demands on the industry. Advantages and disadvantages of these metals and alloys for the various uses to which they are put are considered in this article.

IN this brief review of specialized metals and alloys that are used in the various branches of the electrical industry we have attempted to survey these materials according to the type of applications and have listed them under the following general headings:

1. Resistor materials, including heating elements, thermocouples, and materials having controlled temperature coefficients of resistivity.
2. Bimetals, including both thermostatic bimetals and inlay and overlay metals.
3. Contact alloys.
4. Resistance welding electrodes.
5. Alloys with special magnetic characteristics.
6. Materials used in electronic tubes and X-ray tubes.
7. Special alloys for meters, such as pivot bearings and spring materials.
8. Miscellaneous applications.

RESISTOR MATERIALS

The standard resistor materials for heating elements are nickel-chromium alloys or nickel-chromium-iron alloys. In the straight nickel-chromium alloys, the analysis usually is 80 per cent nickel and 20 per cent chromium, whereas, in the nickel-chromium-iron alloys, the analysis is 60 per cent nickel, 15 per cent chromium, remainder iron. Real advancements have been made in recent years in the fabrication of these materials by employing special fabrication methods which include the use of specialized deoxidizers, such as zirconium, or materials from the second group of the periodic system. In Europe it is claimed that vacuum melting of these alloys greatly improves their life and ductility. Also, melting under hydrogen is said to give excellent products. In view of the present shortage of nickel, attention is drawn to a series of alloys which are iron-base alloys containing chromium and five to ten per cent aluminum. This class of alloys can be produced with a specific resistivity approximating that of standard nickel-chromium alloys. The materials have a higher melting point than nickel-chromium alloys and, therefore, can be used for higher temperature ranges as electric heating elements. These alloys have certain disadvantages, particularly low strength at high temperatures and low corrosion resistance if used in the form of fine wires. Some are also brittle at room temperature.

For work at very high temperatures pure molybdenum is used. In this case it is necessary to use a protectiv atmosphere, such as hydrogen. It is claimed that specia cracked gases may be used also; however, there exist the danger that molybdenum may be carburized and thereby embrittled. In recent years a molybdenum heating element for operation in air has been introduced. In this case the molybdenum is covered by a special refractory coating, and beryllium oxide is used as the laye next to the pure molybdenum. In addition to pure molybdenum it is also possible to use molybdenum-tungsten alloys for heating elements; however, the actua use of such alloys is very limited.

A new series of alloys has been announced which i supposed to produce extremely high values of resistivity of the order of 200 microhms per cubic centimeter. These are manganese-base alloys containing over 50 per cent manganese, the remainder being nickel and copper. These alloys are not intended for heating elements, bu are planned primarily for use in various branches of the electrical industry as fixed or variable resistors. I appears that until the present these materials have been used to a limited extent only because of manufacturing difficulties. Some of them can be produced with controlled temperature coefficients of resistivity, depending upon the composition and heat treatment. Some are comparable to manganin and are characterized by having a low thermoelectric force versus copper, a property of importance in the construction of meters of high sensitivity.

A number of silver base alloys have also been developed recently, such as silver-manganese-tin alloys: 80 per cent silver, 17 per cent manganese, 3 per cent tin. Here again the temperature coefficient varies with the composition and heat treatment. Alloys of this type approach a zero temperature coefficient over a range o 0–200 degrees centigrade, and, for alloys containing ten per cent manganese, ten per cent tin, and the remainder silver, it is possible to produce a negative temperature coefficient which is desirable for compensating resistances

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Essential substance of an address presented at the symposium on rare and precious metals of the annual fall meeting of the American Institute of Mining and Metallurgical Engineers, Cleveland, Ohio, October 13, 1942.

Franz R. Hensel, a member of American Institute of Mining and Metallurgical Engineers, is consulting engineer with P. R. Mallory and Company, Inc., Indianapolis, Ind.

Alloys of palladium and silver, containing about 56 per cent palladium, have a temperature coefficient lower than manganin, possess excellent resistance to tarnishing, and have good electrical contact characteristics. These properties fit them for instrument application, particularly when sliding contacts are involved.

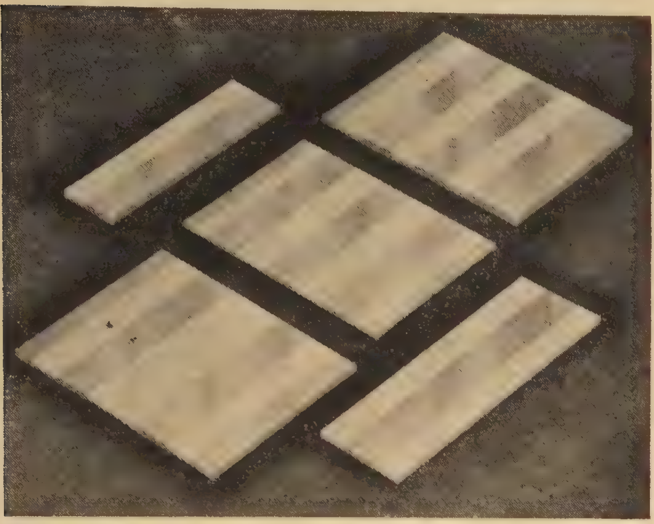

Figure 1. Inlay metal slabs faced with fine silver

Thermocouples. In the field of thermocouples, the standard combinations such as platinum versus platinum-rhodium, chromel-alumel, iron-constantan and copper-constantan, are still used extensively. A newer-type thermocouple which has been used in recent years consists of nickel versus nickel-molybdenum. The advantage of this combination apparently consists in its stability in reducing atmospheres of the cracked hydrocarbon-air type. It is useful to about 1,200 degrees centigrade in such atmospheres.

In addition, other thermocouple combinations for high temperatures have been suggested, such as tungsten versus molybdenum and silicon carbide versus graphite. The former combination has been used in steel-melting practice with a protection tube. It is characterized by a rather low thermoelectric force and is therefore suitable only for high-temperature measurements.

BIMETALS

In the field of thermostatic bimetals, the standard alloys still seem to be useful for the majority of applications. The standard combinations are Invar on brass, austenitic steels versus Invar or austenitic steels versus 42 per cent nickel steel. Recently a high-manganese alloy, containing about 75 per cent manganese, 15 per cent nickel, and 10 per cent copper, has been suggested as a material for the high-expansion side of a thermostatic bimetal.

In addition to bimetals, recent needs have also brought about the manufacture of trimetals. In many cases it was necessary to improve the current-carrying capacity of thermostatic bimetals, and a layer of cadmium-copper between Invar and brass has solved this problem. Thermostatic bimetals have also been suggested where the low-expansion side consists of molybdenum, however; such specialized combinations are used only in very rare instances.

The study of alloys having a low coefficient of expansion has resulted in certain new materials of this type. Platinum alloys containing between 40 and 50 per cent iron, when properly heat treated, have a negative coefficient of thermal expansion over the range of 20–70 degrees centigrade. Attempts have been made to pro-

Table I. Resistor Materials Including Alloys for Thermocouples and Alloys Having Low Temperature-Resistance Coefficients

Name	Iron	Chromium	Nickel	Cobalt	Aluminum or Carbon	Resistivity	Ultimate Tensile Strength (Pounds Per Square Inch)	Melting Point (Degrees Centigrade)
Resistor Alloys								
Nichrome IV		20	80			108 microhms/cm^3 650 ohms/mil ft	110,000	1,320
Nichrome	25	15	60		0.12 C	112 microhms/cm^3	100,000	1,350
Chromax castings	50	15	35				60,000	1,480
Number 193 alloy	68	2	30			91.3 microhms/cm^3	80,000	Low temperature
Kanthal	67	25		3	5 Al	Approximately 810 ohms/mil ft		
Alcress	70	20			5 Al	800 ohms/mil ft		
Ohmax	75				10 Al	1,000 ohms/mil ft		
Alchrome 3	84	14			3 Al			
Thermocouple Alloys and Combinations								
Constantan—45 per cent Ni, 55 per cent Cu						48 8	135,000 to 63,000	1,210
Pt versus pt—10 Rh						Good for 2,800 F continuous or 3,000 F maximum		
Pt versus pt—13 Rh						Good for 2,800 F continuous or 3,000 F maximum		
Chromel versus Alumel						Good for 2,400 F maximum (calibration changes in reducing gases)		
Iron-Constantan						Good for 1,400 F continuous		
Copper-Constantan						Good for 700 F continuous or 1,000 F maximum		
Alloys of Low Temperature-Resistance Coefficient								
Invar	63.5		36.5	0.88×10^{-6} per degree centigrade		66.4 microhms/cm^3	72,500	
Super-Nilvar	64		31	5 Co	0×10^{-6}		Hot rolled	
Kovar and Fernico	54		28	18 Co				
Ferrichrome	37	8	30	25 Co				
Elinvar	52	12	36	Low-coefficient elastic modulus				

duce materials having low coefficients of expansion combined with high elastic properties, such as Invar with the addition of beryllium to make the alloys susceptible to heat treatment. It is reported that Invar with one per cent beryllium has a Brinell hardness of 365 after aging at 932 degrees Fahrenheit for one hour. Also, a stainless-type Invar has been developed, consisting of cobalt, iron, and chromium, and the maximum properties have been found with 54 per cent cobalt, 37 per cent iron, 9 per cent chromium.

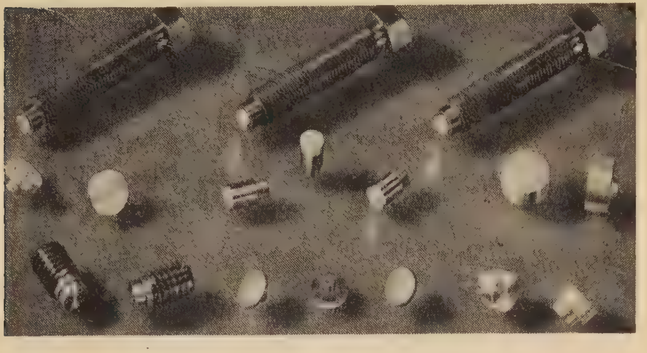

Figure 2. Typical platinum- and platinum-alloy-faced contacts

Alloys having low temperature coefficients of expansion are used extensively for glass-sealing purposes, and in this case it is necessary to match the alloy with the glass into which it is to be sealed. A material used extensively for this purpose is an iron-nickel-cobalt alloy, containing about 54 per cent iron, 18 per cent cobalt, and 28 per cent nickel, which has a higher coefficient than Invar, but also a higher inflection point. In addition to these alloys, there are quite a number of chrome-iron alloys, nickel-iron-cobalt-chromium alloys, and similar compositions which are used for specific purposes.

In the field of overlay and inlay metals, advances have been made in bonding such materials as silver to steel, silver to copper-base alloys, copper to steel, and copper alloys to steel. A development which has been necessitated by the shortage of material is the fabrication of commutator segments of steel with a silver facing. It is quite possible that this development will result in a real improvement, because the strength of the steel will permit higher speeds of rotation without causing yielding and deformation of the commutator segments.

In connection with commutators, attention might also be called to the development of new brush materials, such as silver graphite working against a copper commutator: for example, in heavy d-c generators. It was found that with this combination a much lower voltage drop could be maintained, particularly when the polarity of the brush was positive with respect to the commutator.

Unquestionably the work on clad metals will be extended considerably as a result of the shortage of strategic materials. For instance, the use of silver-clad steel wire and silver-clad steel strips for current-carrying purposes has been suggested, and materials of this type are actually being produced.

CONTACT ALLOYS

The development of new contact alloys has been quite rapid, both new precious-metal alloys and composite metals. The use of platinum and iridium is restricted today almost exclusively to electrical purposes, such as make-and-break or sliding contacts. The platinum-ruthenium alloys have replaced to a certain extent the platinum-iridium alloys; however, the latter are still used for a large number of applications, particularly magneto contacts. Palladium and its alloys, and silver, gold, platinum, and other metals have found specialized uses in relays.

Composite metal compositions, such as Elkonites which are a combination of precious metals and refractory metals and their compounds, are used extensively for current-carrying and arcing contacts. New developments have resulted in materials with high arcing resistance and decreased contact drop. Metal combinations, such as silver and graphite, silver and nickel, and silver and cadmium oxide, have found use in certain circuit-breaker applications.

The field of heavier-duty aircraft relays has required the development of specialized contact materials for d-c applications of medium voltage and high current which will stand up when operated at low temperatures and reduced pressures. The construction of the relay and its electrical requirements also necessitate the mounting of these contacts on high-strength high-conductivity copper alloys, such as copper-cadmium alloys, copper-chromium alloys, and copper alloys hardened with special intermetallic compounds such as nickel silicides, cobalt, and nickel beryllides.

Improvements have also been made in copper-base contact alloys, such as contactor contacts, by such additions as selenium, lead, and tellurium. Materials of this class have less tendency to stick or weld together when making large currents. A contactor contact material, containing substantial amounts of cadmium and hardened by cobalt silicide, has found large application in

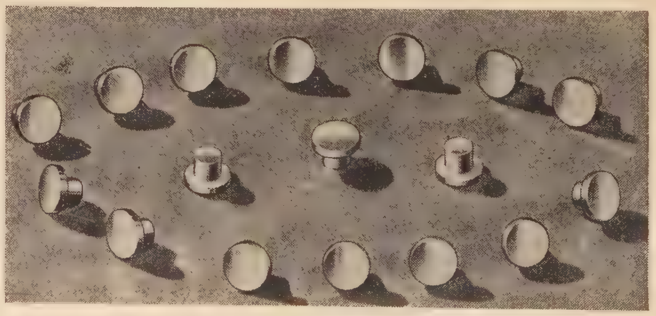

Figure 3. Solid rivet-type contacts of palladium alloy used in automobile voltage regulators

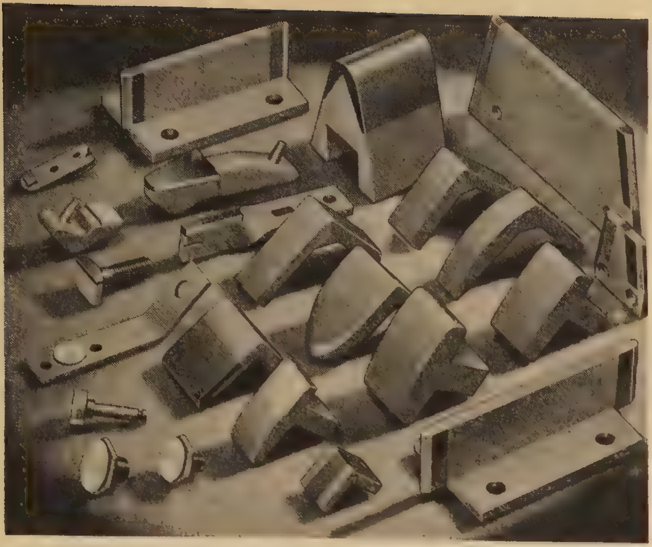

Figure 4. Elkonite-faced arcing tips for heavy-duty circuit-interrupting equipment

the form of contacts for timing equipment in resistance-welding machines.

RESISTANCE-WELDING ELECTRODES

For spot welding and seam welding the electrode materials, as well as the structural parts of resistance-welding machines such as arms and holders, are being fabricated from special age-hardened high-conductivity high-strength alloys: for example, copper-chromium alloys or copper alloys hardened with intermetallic compounds, such as silicides, beryllides, and phosphides. Advances have been made in producing sound copper-chromium castings by the utilization of lithium. Copper-base alloys containing nickel-silicide have been improved by the addition of zirconium. Such nickel-silicon-zirconium bronzes may represent an ideal substitute for certain beryllium-bearing copper alloys in view of the present shortage of beryllium.

The development of composite metal compacts such as Elkonites has resulted in materials having very high strength, combined with high hardness and conductivity. This progress has been made possible by utilizing age hardening. It is possible today to produce materials with a 50 Rockwell *C* hardness and more than 20 per cent electrical conductivity. It is to be expected that additional uses will be found for such materials, in view of their great wear resistance, both mechanical and electrical, and also because of the low contact drop that can be maintained. This type of material is used extensively for hot upsetting purposes in the present war-production program.

MAGNETIC MATERIALS

In addition to the improvement of the standard permanent-magnet steels, considerable progress has been made with the aluminum-nickel-iron magnet materials made either in the form of castings or by powder metallurgy. The addition of elements such as cobalt, titanium, and copper has resulted in improved magnetic properties. With sintered magnets, the addition of metal hydrides was found to be of advantage. The nickel-titanium-cobalt-iron magnet materials were found to be difficult to produce and are not yet in active use.

Oxide-powder magnets have advantages such as high specific resistivity and low density. The oxide-powder magnets consist of mixtures of magnetite, ferric oxide, and cobaltic oxide, and they are magnetized during cooling, from about 500 degrees centigrade.

Copper-base permanent-magnet materials have been developed, containing about 60 per cent copper, and the remainder nickel, cobalt, and iron. Such materials have a coercive force of 500 oersted and a remanence of about 3,000 gausses. The material can be heat treated but, even in this condition, it is quite ductile and lends itself to forming operations which are impossible with other permanent-magnetic materials.

High coercive forces also have been found in platinum-iron alloys, consisting of 50 atomic per cent iron, which corresponds to about 22.2 per cent iron by weight. It is possible to obtain a coercive force of 1,500 oersteds with a residual induction of 5,800 gausses. Similar properties are obtained with platinum-cobalt alloys containing 50 atomic per cent of cobalt, which corresponds to 23.3 per cent cobalt by weight. With platinum-cobalt it is possible to obtain coercive forces up to 3,700 oersteds. In both alloys the heat treatment is quite critical.

High coercive forces also may be obtained with the Potter alloy which is a silver-base material containing 87 per cent silver, 8.8 per cent manganese, and 4.2 per cent aluminum. This material is similar to the Heusler alloys, except that silver is substituted for copper.

In the production of magnetically soft materials such as pure iron, iron-silicon alloys, iron-aluminum alloys, and iron-nickel alloys, improvements have been made by the addition of smaller percentages of such metals as molybdenum, chromium, and copper, and also by new manufacturing methods based on special annealing and rolling techniques. The field of application for magnetically soft materials is quite extensive, and special compositions have been developed for applications where

Table II. Thermostatic Bimetals

Number	Composition		Useful Range (Degrees Centigrade)
	High Expansion	Low Expansion	
1	Iron, 27 nickel, 5 molybdenum	Invar (36 nickel, iron)	25–190
2	Iron, 27 nickel, 5 molybdenum	42 nickel, iron	60–500*
3	Nickel	Invar	60–190
4	Nickel	42 nickel, iron	20–350
5	42 nickel, 5 molybdenum, iron	42 nickel, iron	130–400
6	42 nickel, iron	Invar	250–340
7		Platinum, 45–55 iron	
8		Invar+1 per cent beryllium	Increased elastic properties

* Inflection point near 300 degrees centigrade.

high permeability is required at low induction, or where a high saturation limit is required at high field strength, or where a combination of high permeability with a certain specific electrical resistivity is required.

Mention also might be made of the 30 per cent nickel-iron alloy and Permalloy containing considerable molybdenum, where changes in permeability with temperature are required to compensate for temperature errors. Further in this direction, alloys have been developed which lend themselves readily to production from metal powders with additional agents such as tin and phosphorus. Powdered alloys of this type are used for specialized iron cores. In most cases the material which is used for iron cores is relatively pure fine-grained carbonyl iron of a mesh size of several microns (2–7), having well-insulated iron particles. This type of iron core is used for high-frequency applications where it is necessary to obtain the greatest possible increase in inductance with a minimum amount of energy loss due to eddy currents and hysteresis.

MATERIALS FOR ELECTRONIC TUBES, X-RAY TUBES, LAMPS

In the construction of electronic tubes refractory materials, such as tungsten, molybdenum, and tantalum, are used extensively. Tungsten is used for lead-in wires, heating elements in vacuum tubes, electrode supports, anodes, rectifier-tube cathodes, and anticathodes in X-ray tubes. Other varieties of tungsten used are thoriated tungsten, containing 0.7 per cent or $1^1/_2$ per cent of thorium, for such applications as glow cathodes.

A large amount of tungsten is used for filament wire or as electrode tips in fluorescent-lighting tubes.

Table IIA. Alloys for Sealing Into Glass

	Expansion Coefficient	Thermal Conductivity (Cal/Cm. Sec Grad)	Specific Resistivity (Mm²/M)	Glass (Corning)
Platinum	90.7×10^{-7} (25–100 C.)	0.167	0 108	G-1 and G-5
$47^1/_2$ Ni, 50 Fe, 1 Cr, 1 Mn	89×10^{-7}	0.038	0 45	G-1 and G-5
Platinite 48 Ni, 52 Fe, 0.15 C	90×10^{-7}	0.038	0.45	G-1 and G-5
Platinum-clad wire Pt on 48 Ni, 51 Fe	90×10^{-7}	..	....	G-1 and G-5
Copper-clad wire Radial	$80–100\times10^{-7}$	0.4	0.04–0.06	G-1 and G-5
Cu on 42 Ni, 58 Fe Axial	$61–65\times10^{-7}$			
Borax coated 25–30 Cr, Fe remainder	$95–100\times10^{-7}$ (20–100 C.)	0.05	0 5	G-1, G-5, G-6, G-8
EMK 71 Fe, 10 Mo, 19 Co, 0.8 Si	$90–95\times10^{-7}$	0.05	0.33–0.37	G-1, G-5
Fernichrome 37 Fe, 30 Ni, 25 Co, 8 Cr	92×10^{-7}			G-5
Wonico 80 W, 13 Ni, 5 Co	55×10^{-7}		0.13	Osram Na hard glass
Tungsten	$40–45\times10^{-7}$	0 38	0 06	Uranium Nonex
Molybdenum	$53–55\times10^{-7}$	0 35	0.06	G-71 G 705 AO
Kovar; Fernico	47 450 C.	0.09	0.27	G 705 AJ
Ni 28, Co 18, C 0.1, Fe	56 500 C.			G-71; G 705 AO

Molybdenum has a combination of high strength, high melting point, and ductility and, therefore, is used for grid supports, grids, anodes, and cathodes.

Tantalum is employed for its "getter" properties in electronic tubes. Tantalum can be readily degassed, a property of importance in this application. In addition to tantalum, certain tantalum-tungsten alloys are employed in tube construction.

Materials used for cathodes in photocells are caesium, rubidium, potassium, and selenium. In this connection caesium, rubidium, and potassium show a quicker electric response to incident light than selenium does. However, it is necessary to impress a small voltage across the cells containing caesium, rubidium, and potassium and, in most uses, to amplify the small currents they generate when illuminated. Selenium has the property of generating its own voltage when light strikes it and furnishes current which is of rather larger magnitude than that supplied by caesium, rubidium, or potassium.

Selenium for this use, as well as for use in rectifiers, must be of high purity, about 99.85 per cent. Its conductivity may be increased by incorporation of controlled amounts of certain selenides, and the conductivity is increased further by a carefully controlled annealing from near the metal's melting point. In this connection, some recent experimental results have been published on the subject of a photoelectric combination of cuprous oxide on copper where the oxide layer has been electrolytically deposited.

Sodium is used for sodium vapor lamps and, in the form of an amalgam, for liquid cathodes in tube rectifiers.

Zirconium-coated molybdenum is used as a substitute for tantalum. The zirconium coating is produced either by electroplating or by spraying onto the plates a paste containing metallic zirconium or zirconium hydride.

In Europe ductile zirconium has been used as a sub-

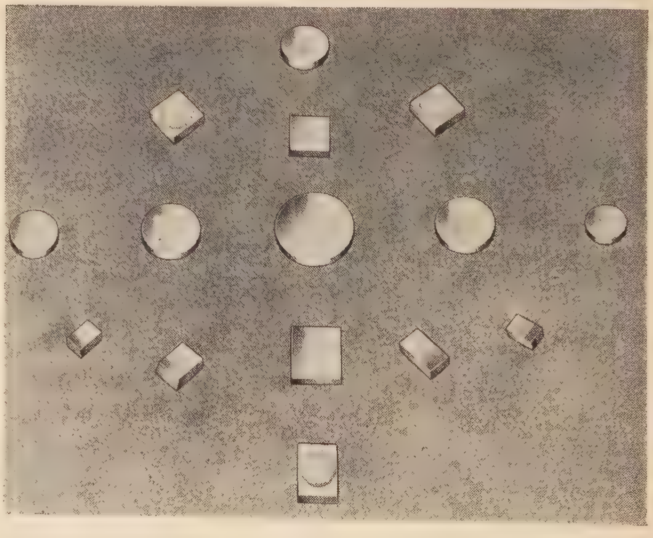

Figure 5. Silver-tungsten parts for direct-resistance brazing into contact assemblies

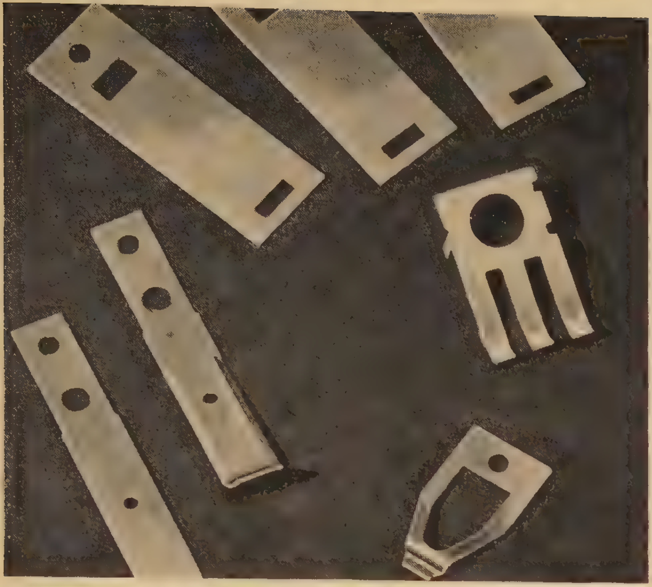

Figure 6. Typical contacts springs made of copper-cadmium, copper-chromium, and other copper alloys

Table III. Alloys With Special Magnetic Properties—Magnetically Soft Alloys*

Name	Composition
Hipersil	Si steel—controlled grain orientation High permeability and one-third more flux capacity than standard Si-steel
Hydrogen–iron	0.005 per cent C, 0.028 per cent Mn, all others 0.003 per cent or less
High Permeability at Low Induction	
Permalloy	30–90 per cent Nickel, remainder Fe ± Cr or Mo $78\frac{1}{2}$ per cent Ni best. Heat treat
Mumetal	76 per cent Ni, 6 per cent Cu, 1.5 per cent Cr, Fe remainder
1,040 alloy	72 per cent Ni, 14 per cent Cu, 3 per cent Mo
High Permeability for Higher Field Strength	
Hypernik Nicaloi	45–50 per cent Ni, remainder Fe
Megaperm	65 per cent Ni, 10 per cent Mn, remainder Fe
Moderately High Permeability With High Electrical Resistance	
Rhometal	40–45 per cent Ni, 5 per cent Cr, 3 per cent Si
Constant Permeability Over Range of Flux Densities	
Perminvar	20–75 per cent Ni, 5–40 per cent Co, ± Mo, Heat treat
Conpernik, and so forth	40–55 per cent Ni—Heat treat
Isoperm	36–50 per cent Ni, 9–15 per cent Cu } Precipitation types
Isoperm	40–60 per cent Ni, 3– 4 per cent Al } Precipitation types
Compensator Types (High Temperature Coefficient of Permeability)	
	29–32.5 per cent Ni, remainder Fe; Mn, Cr, Si
	70 per cent Ni, 30 per cent Cu; Fe or Mn plus Si

* See American Society of Metals *Handbook*.

stitute for molybdenum in tube construction because of its excellent "getter" properties. Base metals extensively used in tube construction are nickel and nickel-base alloys which have high strength at elevated temperatures: for example, a material which is age hardened by means of the addition of titanium, special pure irons, such as gas-free Svea iron, or sintered iron and certain copper alloys.

Mercury is used extensively in rectifiers as a liquid cathode. High-purity mercury must be used to prevent reignition.

Pure beryllium is used in X-ray apparatus for X-ray windows. Recent work has shown that a small addition of titanium is very helpful in producing sound and dense beryllium.

Consideration has been givento the use of gallium as a substitute for mercury for cathodes in rectifiers.

Metals characterized by special thermionic properties are nickel alloys containing barium. Recently it has been reported that increased ionization of spark gaps, and hence lower sparking voltage, can be obtained by incorporating polonium into nickel alloys. However, the usual oxide cathode used in radio tubes consists of a nickel core coated with a mixture of barium and strontium oxides and contains a trace of elemental barium developed during the activation process. The important use for such materials, however, is as electrodes for spark plugs where it is necessary to decrease the sparking voltage and maintain it at a constant level.

SPECIAL ALLOYS FOR METERS

In meters it is important to have bearings which have high wear and corrosion resistance. Formerly, precious stones, such as sapphires, were used extensively for this purpose, although certain glasses are now finding some use as emergency substitutes. In recent years, osmium-base materials which are hardened further by the addition of other platinum group metals have proved to be excellent substitutes. These osmium-base alloys are made either by melting or sintering. The alloys are extremely hard and very noble. In some cases nickel or cobalt may be added advantageously to these materials.

Alloys of similar compositions are used for long-life phonograph needles and pen-point alloys, and alloys

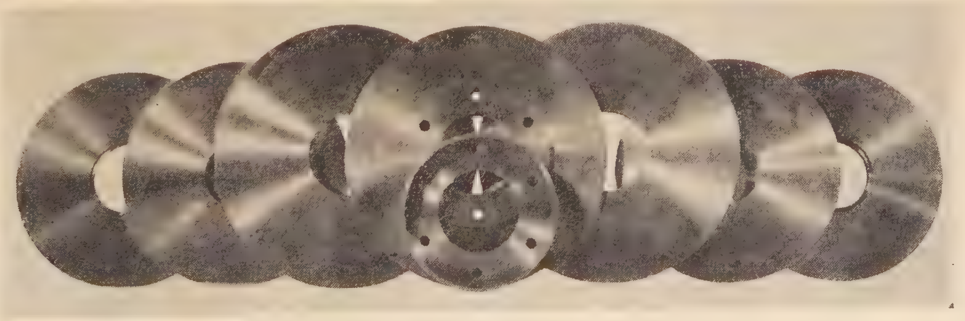

Figure 7. Resistance-welding electrodes (seam-welding rings and disks) made of copper-chromium alloy

Table IIIA. Permanent Magnet Materials*

Type	Composition
Magnet Steels	
C-Mn	0.6 C, 0.8 Mn
Cr	0.6–1.0 C, 0.2–0.4 Mn, 0.9–6.0 Cr
W	0.7 C, 0.3 Mn, 0.2 Cr, 5.5 W
Co	0.9 C, 0.35 Mn, 4.75 Cr, 1.25 W, 8.5 Co
Cr-Mo	4 Cr, 0.35 Mo
Cr-W	0.5 Cr, 6 W
Cr-Co	9 Cr, 16 Co, 1.3 Mo
Co-W	2–5 Cr, 17 Co, 8.75 W
Precipitation Hardening Types	
Fe-Ni-Al	24–30 Ni, 9–13 Al, Fe
Fe-Ni-Al-Co	24–30 Ni, 9–13 Al, 5–10 Co, Fe
Fe-Ni-Co-Ti	10–25 Ni, 15–30 Co, 8–25 Ti, Fe
Fe-Co-Mo	12 Co, 16 Mo, Fe remainder
Fe-Co-V	36–62 Co, 6–16 V, 30–52 Fe (Vicalloy)
Special	
Heusler type	65 Cu, 20 Mn, 13 Al, 1 Fe, Si, Pb

* See American Society of Metals *Handbook*.

consisting essentially of hard carbides are also used for phonograph needles.

Spring materials are extremely important in meters, and increasing use is found for drift-free precision springs made of age-hardening copper-beryllium alloys or special nickel alloys such as Z nickel.

Alloys suitable for precision resistance wires or compensating resistance wires were mentioned previously and also materials characterized by a low temperature coefficient of the modulus of elasticity, such as Elinvar, which is an Invar with the addition of 12 per cent chromium.

OTHER APPLICATIONS

Dry Disk Rectifiers. There are three types of dry disk rectifiers, the copper-oxide rectifier, the cupric-sulphide rectifier, and the selenium rectifier. It appears that the selenium rectifier has a large number of applications, and a special high-purity selenium has been developed for these purposes. The actual preparation of the rectifying layers is quite complicated, and a large amount of patent literature has appeared on this subject recently. Among the latest reports on this work, it has been claimed that useful rectification can be obtained from junctions between selenium and cadmium, tin, or bismuth. Another rather recent development has been the selenium versus aluminum junction. In the cupric-sulphide rectifier, pure magnesium is used against cupric sulphide, and this combination is treated in such a way as to form a rectifying layer.

It has been disclosed recently that the copper-cuprous-oxide-type junction can be made by electrolytic deposition of a layer of cuprous oxide on copper.

In a wet type of rectifier, tantalum has found widespread use because of its ability to form a rectifying layer when immersed in certain solutions. Tantalum's resistance to corrosion is useful in this application. Such rectifiers have found their places as reliable charging sources for railway signal batteries, telephone-exchange battery chargers, and "trickle" chargers for storage batteries.

Table IV. Special Alloys for Meters*

Low Temperature-Resistance Coefficient		
Manganin	84 Cu, 12 Mn, 4 Ni	Resistivity $=48\times10^{-6}$ per cubic centimeter
High Mn	67 Mn, 28 Ni, 5 Cu	Resistivity $=220\times10^{-6}$ per cubic centimeter
High Mn	60 Mn, 39 Ni, 1 Cu	Resistivity $=220\times10^{-6}$ per cubic centimeter
Damping	87 Mn, 13 Cu	Quench 950 C. Age 450 C
Silver alloy	10 Mn, 10 Sn, 80 silver	Age. Negative coefficient
Silver alloy	17 Mn, 3 Sn, 80 silver	Age. Zero coefficient
Palladium-silver alloys	56 palladium-44 silver	
Magnetic Shunt Materials—Very High Temperature Coefficient of Permeability		
Ni-Cu type	70 Ni, 30 Cu ± 2 per cent Fe or ± 1 per cent Mn plus Si	
Ni-Fe type	30 to 40 Ni, remainder Fe ± Mn, Cr, Si	
Low Temperature Coefficient Modulus of Elasticity		
Elinvar	36 Ni, 12 Cr, 52 Fe	
Elinvar—modified	34 Ni, 4.5 Cr, 2 W, remainder Fe	

* Also see Table I.

Mercury.—In addition to the application mentioned for electronic tubes, mercury is used for mercury switches, high-vacuum diffusion pumps, and thermometers, and as a sealing medium for vacuum-tight seals. Recently, also, an amalgamation process has been developed, particularly suitable for joining silver to copper.

Fusion Welding.—Pure tungsten is used for the electrodes in atomic hydrogen welding and also in a process of welding magnesium under a helium atmosphere. This latter process has been perfected for commercial use only within the last few months.

Capacitors. Tantalum is being used for a special type of electrolytic capacitor. A spongy tantalum material is pressed from powders which produces a condenser plate having a large surface area per unit of space occupied.

Bismuth. Bismuth may find some use in the electric-motor field because of its property of changing electrical resistance when inserted into a magnetic field. The resistance of bismuth increases when it is inserted into a transverse magnetic field. For a given field strength, the percentage change in resistance increases with a decrease in temperature. At a given temperature, the percentage change in resistance increases with an increase in field strength; for example, at a constant temperature of 18 degrees centigrade, the percentage change in resistance is 12 per cent at 4,000 gausses, 32 per cent at 8,000 gausses, 104 per cent at 20,000 gausses.

CONCLUSIONS

This review has touched upon only certain high lights of the subject under discussion. It is evident, however, that the electrical industry is vitally interested in the development of highly specialized metallurgical products. There is no question that this trend will be emphasized still more as time goes on, and we may expect new and important metallurgical developments from the research laboratories of companies closely connected with various branches comprising the electrical industry.

Ultrashort Electromagnetic Waves

V—Radiation

ANDREW ALFORD
MEMBER AIEE

In the design of radiators or antennas for ultrashort waves a complete solution by Maxwell's field equations is usually not practicable and, in many cases, not possible. It is therefore necessary to resort to engineering approximations based upon known physical phenomena. In this article the author discusses a method to be employed when the distribution of the current and the charge over the surface of the radiator are known. A subsequent issue will carry a continuation of this article in which a second method for the calculation of the field in space will be developed on the basis of the known field distribution in the immediate vicinity of the radiator as obtained from experimental data. The author is well known in the field of antenna design and is to a large extent responsible for the development of the instrument landing system used by the Civil Aeronautics Authority. This article is the fifth in a series presented originally as lectures before the basic science group of the AIEE New York Section.

PAUL C. CROMWELL, Chairman, Symposium Committee
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TWO previous lectures[2,4] have been devoted to the subject of propagation of electromagnetic energy along transmission lines and guides. In wave guides and transmission lines the lines of force are allowed to propagate along one dimension only; the propagation along the remaining two dimensions is restricted. Thus, for example, the lines of electric and magnetic forces are confined to the space between the outer and the inner conductors of a concentric transmission line and are allowed to travel only in the direction of the axis of these conductors. Similarly, in a hollow wave guide the waves propagate mainly along the axis of the guide.

In this paper we shall consider the phenomena which take place when electromagnetic energy is allowed to spread out into unlimited space. In practice these phenomena occur when a transmission line or a hollow wave guide is left open-ended, and the waves which propagate along them are thus permitted to continue their travel into unbounded space.

The nature of the open end determines what proportion of the power is reflected back into the guide and what is radiated into space. The open end acts as a transformer between the two modes of propagation. The impedance of a guide is usually very different from the impedance of open space. For this reason, when a guide is terminated abruptly, the impedance match at the open end is very poor; most of the power which arrives at the end is reflected back into the guide, and only a small portion of the power is radiated into space. When it is desired that a greater portion of the power be radiated into space, the end of the transmission line or guide is so arranged that a better match of impedance of free space and of the guide is obtained. Such modified ends are usually referred to as electromagnetic horns and antennas, or radiators.

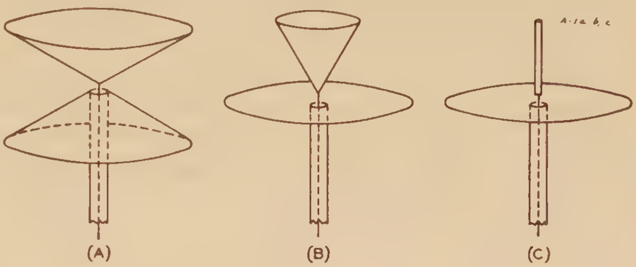

Figure 1. Examples of radiators

It is difficult to draw a line between what is called an antenna and what is called an electromagnetic horn, because there is no real distinction between them. This difficulty becomes quite evident from Figure 1 in which there are shown several radiating terminations of a concentric transmission line. Termination *A* would almost certainly be called an electromagnetic horn. Termination *C* is a familiar antenna. Termination *B* may be called anything you like.

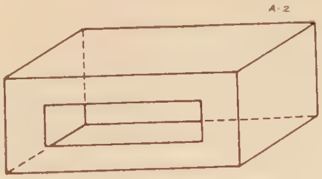

Figure 2. A metal box with an aperture

There are still other types of radiators. For example, an opening in a metal box which contains high-frequency circuits, as in Figure 2, or a looplike end of a short-

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circuited two-wire transmission line, as in Figure 3, are also radiators. These examples, of course, do not exhaust the list of various forms of radiators, but they are sufficient to give us some idea of the variety of shapes which radiators can have.

For the purposes of design and other reasons, it is often necessary to be able to calculate the radiation field of the various types of radiators with some accuracy. At the present time there are three different approaches which are in use. Which one of these three methods is used in a particular case depends primarily on the nature of the problem.

Method 1. This method is used when the distribution of currents and charges over the surface of the radiator is known, either from other calculations or from experiments.

Method 2. This method is used when the distribution of field in the immediate vicinity of the radiator is known from experimental data or from other sources.

Method 3. This method is used when the distribution of currents and charges on the surface of the radiator, as well as the field distribution in the immediate vicinity of the radiator, is in doubt. In such cases one must obtain that solution of Maxwell's equations which satisfies the boundary conditions of the problem. From such a solution not only the field at a distance, but also the current distribution along the radiator, can be calculated. This method is applicable to all radiation problems. Of the three methods it is the most difficult one to use, particularly when the shape of the radiator is not very simple. It will not be possible, within the confines of this paper, to describe in detail all three methods. We shall therefore confine ourselves to the first two, the first method being covered in this article and the second in the subsequent one.

The justification of this emphasis on the first two methods is to be found in the fact that these methods, because of their relative simplicity, are used more frequently in engineering calculations.

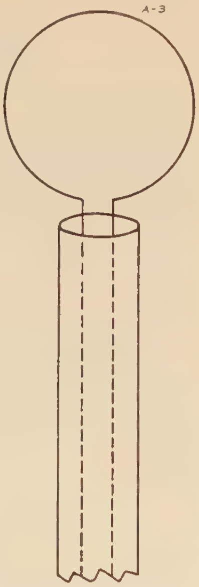


Figure 3. A loop-like radiator

METHOD 1

This method normally is applied to so-called antennas. The application of this method becomes particularly simple when the radiator consists of one or more wires in which the current distribution is sinusoidal.

In order to obtain the equations which are used in method 1, let us calculate the electromagnetic field produced by the currents and charges which are carried by a good conductor C in Figure 4. It will be assumed that the current density at every point on the surface and inside the conductor is known. This quantity is a vector which may have different directions at different points. Let i_x, i_y, and i_z be the components of this vector at a point $P(x', y', z')$ in the conductor. Each of these three components is a function of co-ordinates x', y', z'. Let ρ be the charge density at point $P(x', v', z')$. This is a scalar quantity which is also a function of coordinates x', y', z'.

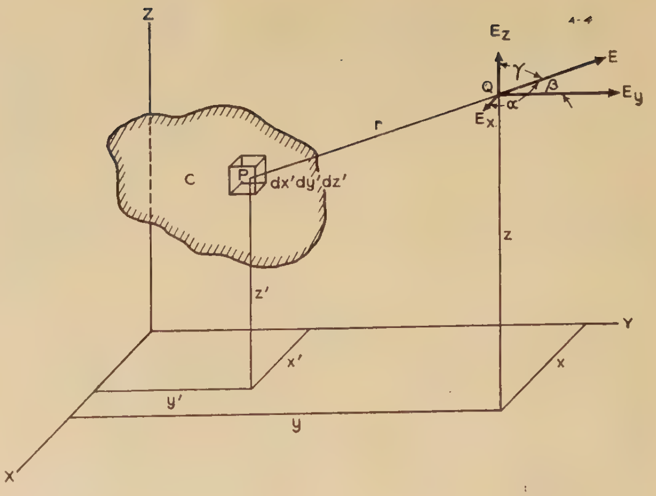
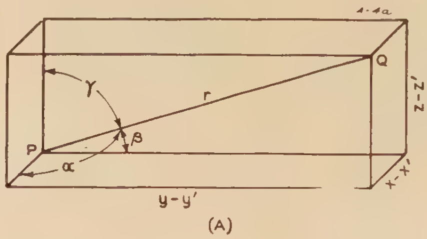


Figure 4

Auxiliary figure to explain scalar potential



$$E_x = E\cos\alpha\beta$$
$$E_y = E\ \cos$$
$$E_z = E\cos\gamma$$
$$\cos\alpha = \frac{x-x'}{r}$$
$$\cos\beta = \frac{y-y'}{r}$$
$$\cos\gamma = \frac{z-z'}{r}$$
$$E_x = E\cdot\frac{x-x'}{r}$$
$$E_y = E\cdot\frac{y-y'}{r}$$
$$E_z = E\cdot\frac{z-z'}{r}$$

In accordance with the law of Coulomb a fixed charge q concentrated at a point $P(x', y', z')$ in free space produces a field $E=q/r^2$ at a point $Q(x, y, z)$ located at a distance $r=\sqrt{(x-x')^2+(y-v')^2+(z-z')^2}$ from P. This field $\boldsymbol{E}$ is a vector which points along line PQ and in the direction from P to Q. The three components of this vector are (see Figure 4a)

$$\left.\begin{aligned} E_x &= \frac{q}{r^2}\,\frac{x-x'}{r} \\ E_y &= \frac{q}{r^2}\,\frac{y-y'}{r} \\ E_z &= \frac{q}{r^2}\,\frac{z-z'}{r} \end{aligned}\right\} \qquad (1)$$

All of these three components can be obtained by partial differentiation of a scalar quantity $V=q/r$ which is called the scalar potential. Since

$$r^2=(x-x')^2+(y-y')^2+(z-z')^2$$

then

$$\left.\begin{aligned} r\frac{\partial r}{\partial x}&=x-x' \\ r\frac{\partial r}{\partial y}&=y-y' \\ r\frac{\partial r}{\partial z}&=z-z' \end{aligned}\right\} \qquad (2)$$

and

$$\left.\begin{aligned} E_x&=-\frac{\partial V}{\partial x}=-\frac{\partial}{\partial x}\left(\frac{q}{r}\right)=\frac{q}{r^2}\frac{\partial r}{\partial x}=\frac{q}{r^2}\,\frac{x-x'}{r} \\ E_y&=-\frac{\partial V}{\partial y}=\frac{q}{r^2}\,\frac{y-y'}{r} \\ E_z&=-\frac{\partial V}{\partial z}=\frac{q}{r^2}\,\frac{z-z'}{r} \end{aligned}\right\} \qquad (3)$$

When the charge density ρ is known at every point in body C, and the charges are static, that is, when they do not vary rapidly with time, the three components of the electric field $\boldsymbol{E}$ can be calculated easily. Since the charge inside volume element $dx'dy'dz'$ around $P(x', y', z')$ is $\rho dx'dy'dz'$ the x component of $\boldsymbol{E}$ due to this charge is

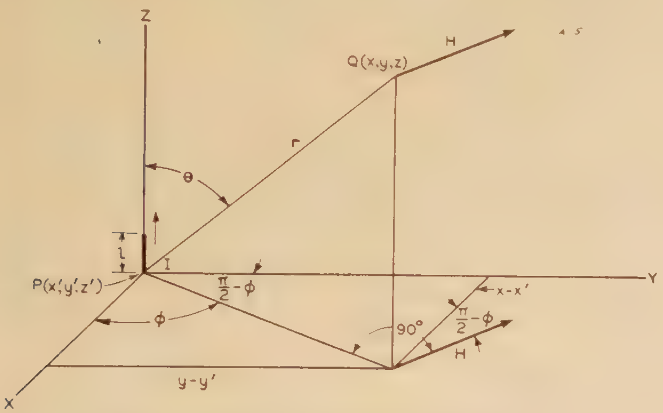


Figure 5. Biot-Savart law for a current element

$$H=\frac{Il}{cr^2}\sin\theta$$

$$dE_x=\frac{\rho dx'dy'dz'}{r^2}\,\frac{x-x'}{r}=-\frac{\partial}{\partial x}\left(\frac{\rho}{V}\right)\cdot dx'dy'dz' \qquad (4)$$

The total E_x is therefore

$$E_x=-\int\!\!\!\int_C\!\!\!\int\frac{\partial}{\partial x}\left(\frac{\rho}{r}\right)dx'dy'dz'=-\frac{\partial}{\partial x}\int\!\!\!\int_C\!\!\!\int\frac{\rho}{r}\,dx'dy'dz'$$

$$=-\frac{\partial V}{\partial x} \qquad (5)$$

where

$$V=\int\!\!\!\int_C\!\!\!\int\frac{\rho}{r}\,dx'dy'dz' \qquad (6)$$

The $\partial/\partial x$ was carried outside the integral sign, because x is a parameter, the integration being performed with respect to x', y', z' and not with respect to x, y, z. This fact allows us to perform partial differentiation with respect to x before or after the integration. The other two components of $\boldsymbol{E}$ are found to be

$$E_y=-\frac{\partial V}{\partial y},\quad E_z=-\frac{\partial V}{\partial z} \qquad (7)$$

where V has the same value as in equations 6 and 5.

The components of the *magnetic* field due to a steady or slowly varying distribution of currents can also be calculated readily by a procedure very similar to that which was just used to calculate the electric field due to a known distribution of charges.

This time we start with Biot-Savart's law (see Figure 5). According to this law a current I flowing through a very short wire of length l located at $P(x'y'z')$ produces at $Q(x, y, z)$ a magnetic field

$$H=\frac{Il}{cr^2}\sin\theta \text{ (in Gaussian units)} \qquad (8)$$

which is directed at right angles to both r and l. In this equation c is the velocity of light. If the wire is directed parallel to the Z axis, as in Figure 5, the three components of the magnetic field H are as follows:

$$\left.\begin{aligned} H_x&=-\frac{Il}{cr^2}\,\frac{y-y'}{r} \\ H_y&=\frac{Il}{cr^2}\,\frac{x-x'}{r} \\ H_z&=0 \end{aligned}\right\} \qquad (9)$$

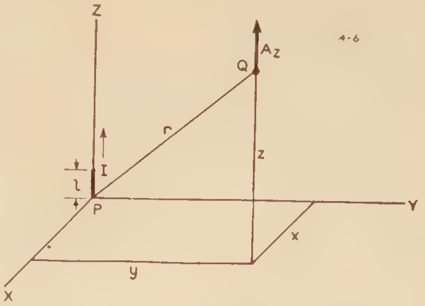
Again, as in the case of the three components of the electric field, all three components may be calculated easily from an auxiliary function $\boldsymbol{A}=\boldsymbol{I}l/cr$. This time, however, this auxiliary quantity itself is a vector and is therefore called vector potential. The direction of vector $\boldsymbol{A}$ is by definition the same as that of current I (see Figure 6).

Figure 6. Vector potential of a current element (I, l)

$$A_z=\frac{Il}{cr}$$

$$A_x=0$$

$$A_y=0$$



If the direction of current I is parallel to the Z axis, then the components of $\boldsymbol{A}$ are

$$\left.\begin{aligned} A_x&=0 \\ A_y&=0 \\ A_z&=\frac{Il}{cr} \end{aligned}\right\} \qquad (10)$$

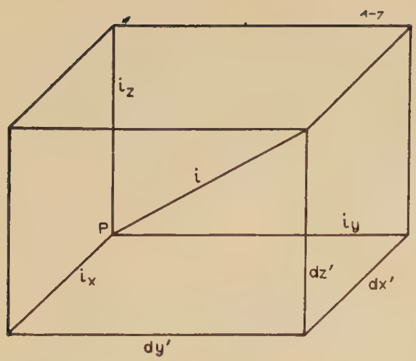


Figure 7. Current intensity i at a point P may be resolved into three components, i_x, i_y, i_z

The components of the magnetic field $\boldsymbol{H}$ may be obtained from the components of vector potential $\boldsymbol{A}$ by the following rules

$$\left.\begin{aligned} H_x&=\frac{\partial A_z}{\partial y}-\frac{\partial A_y}{\partial z}=-\frac{Il}{cr^2}\,\frac{y-y'}{r}\\ H_y&=\frac{\partial A_x}{\partial z}-\frac{\partial A_z}{\partial x}=+\frac{Il}{cr^2}\,\frac{x-x'}{r}\\ H_z&=\frac{\partial A_y}{\partial x}-\frac{\partial A_x}{\partial y}=0\end{aligned}\right\} \tag{11}$$

In vector shorthand these relationships are usually written in one of the following ways

$$\boldsymbol{H}=\text{curl }\boldsymbol{A},\qquad \boldsymbol{H}=\nabla\times\boldsymbol{A},\qquad \boldsymbol{H}=\text{rot }\boldsymbol{A} \tag{12}$$

depending on which particular brand of notation is preferred by the writer.

In order to calculate the magnetic field of currents flowing in the solid conductor C in Figure 4, the following procedure may be used. Let i_x, i_y, i_z be the components of current density $\boldsymbol{i}$ at point $P(x', y', z')$ inside the conductor (Figure 7).

Then, the components of the vector potential due to i_z are

$$\left.\begin{aligned} dA_x&=0\\ dA_y&=0\\ dA_z&=\frac{(i_z dx'dy')dz'}{cr}\end{aligned}\right\} \tag{13}$$

Similarly, the components of the vector potential due to i_y and i_x are

$$dA_y=\frac{i_y dz'dx'dy'}{cr},\qquad dA_x=\frac{i_x dy'dz'\cdot dx'}{cr} \tag{14}$$

The components of the total vector potential are obtained by integration

$$A_x=\iiint\limits_C \frac{i_x dy'dz'dx'}{cr},\qquad A_y=\iiint\limits_C \frac{i_y dz'dx'dy'}{cr},$$

$$A_z'=\iiint\limits_C \frac{i_z'dx'dy'dz'}{cr} \tag{15}$$

From these, the components of the magnetic field are obtained by means of equations 12 or 11. In vector notation these results may be written as follows:

$$\boldsymbol{A}=\frac{1}{c}\iiint\limits_C \frac{\boldsymbol{i}}{r}\,dv \tag{16}$$

$$\boldsymbol{H}=\text{curl }\boldsymbol{A} \tag{17}$$

So far we have considered the case of steady currents or currents varying so slowly that both magnetic and electric fields may be assumed to propagate instantaneously. When the currents vary with time so rapidly that a considerable change in current takes place while the magnetic field due to this current propagates a distance r, we may still calculate the vector potential from equations 16, but this time, however, if we wish to get $\boldsymbol{A}$ at time t, we must use, under the integral, current density $\boldsymbol{i}$ at time $t-r/c$ to allow for time of travel. The quantity r/c is the time taken by the field to traverse distance r when traveling with the velocity of light c. To remind ourselves that we must use the value of current density at time $t-r/c$, we shall write $[\boldsymbol{i}]$ instead of $\boldsymbol{i}$. Therefore

$$\boldsymbol{A}=\frac{1}{c}\iiint \frac{[\boldsymbol{i}]}{r}\,dv \tag{18}$$

$$\boldsymbol{H}=\text{curl }\boldsymbol{A} \tag{17}$$

Applying the same reasoning to the scalar potential of rapidly varying charges, we find that

$$V=\iiint \frac{[\rho]}{r}\,dv \tag{19}$$

where $[\rho]$ indicates that the value of charge ρ is to be taken at time $t-r/c$. The electric field produced by the charges is still given by

$$E_x=-\frac{\partial V}{\partial x},\qquad E_y=-\frac{\partial V}{\partial y},\qquad E_z=-\frac{\partial V}{\partial z} \tag{20}$$

or

$$\boldsymbol{E}=-\text{grad } V$$

This field, however, is only a part of the total field. There is another part $\boldsymbol{E}'$ which appears whenever $\partial H/\partial t\neq 0$. In order to evaluate $\boldsymbol{E}'$ let us consider a volume element whose sides are $dxdydz$ (see Figure 8). Let us assume that, at a point inside the element, there is a magnetic field $\boldsymbol{H}$ whose components are H_x, H_y, H_z. Then $H_z dxdy$ may be regarded as flux which links perimeter $ABCD$. If flux $H_z dxdy$ is varying with time

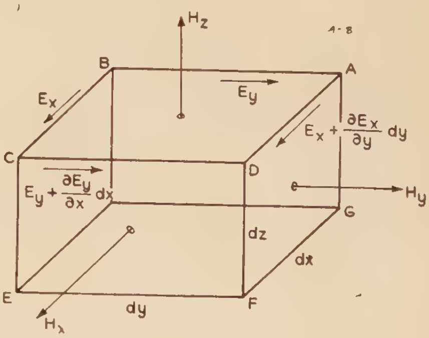

A-8
H_z
B
A
E_x
E_y
$E_x+\frac{\partial E_x}{\partial y}dy$
C
D
$E_y+\frac{\partial E_y}{\partial x}dx$
H_y
G
dz
dx
E
dy
F
H_x

Figure 8. Used in deriving equations 21, 22, 23

$$dE_y=\frac{\partial E_y}{\partial x}\,dx$$

there is produced an electromotive force

$$\frac{1}{c}\frac{\partial(H_z dxdy)}{\partial t}$$

around the perimeter *ABCD*. This electromotive force must be equal to the sum of potential drops around *ABCD*. The potential difference between

B and *C* is $+E_x dx$

C and *D* is $+\left(E_y+\frac{\partial E_y}{\partial x}dx\right)dy$

D and *A* is $-\left(E_x+\frac{\partial E_x}{\partial y}dy\right)dx$

A and *B* is $-E_y dy$

The sum of all potential drops around the circuit is therefore

$$E_x dx' - \left(E_z+\frac{\partial E_x}{\partial y}dy\right)dx + \left(E_y+\frac{\partial E_y}{\partial x}dx\right)dy - E_y dy = \left(\frac{\partial E_y}{\partial x}-\frac{\partial E_x}{\partial y}\right)dxdy$$

and this must be equal to the electromotive force

$$-\frac{1}{c}\frac{\partial H_z}{\partial t}dxdy$$

It follows that

$$\frac{\partial E_y}{\partial x}-\frac{\partial E_x}{\partial y}=-\frac{1}{c}\frac{\partial H_z}{\partial t} \qquad (21)$$

Similar reasoning applied to other components of **E** and **H** yields the following equations

$$\frac{\partial E_z}{\partial y}-\frac{\partial E_y}{\partial z}=-\frac{1}{c}\frac{\partial H_x}{\partial t} \qquad (22)$$

$$\frac{\partial E_x}{\partial z}-\frac{\partial E_z}{\partial x}=-\frac{1}{c}\frac{\partial H_y}{\partial t} \qquad (23)$$

These three equations, 21, 22, 23, may be written in vector notation as one equation

$$\text{curl } \boldsymbol{E}=-\frac{1}{c}\frac{\partial \boldsymbol{H}}{\partial t} \qquad (24)$$

We have already seen that

$$\boldsymbol{H}=\text{curl } \boldsymbol{A} \qquad (17)$$

By substituting this value of **H** into equation 24, we find that

$$\text{curl } \boldsymbol{E}=-\frac{1}{c}\frac{\partial}{\partial t}(\text{curl } \boldsymbol{A})$$

Hence

$$\text{curl } \boldsymbol{E}=\text{curl}\left(-\frac{1}{c}\frac{\partial \boldsymbol{A}}{\partial t}\right) \qquad (25)$$

It is quite clear that

$$\boldsymbol{E}=-\frac{1}{c}\frac{\partial \boldsymbol{A}}{\partial t} \qquad (26)$$

would satisfy equation 25. To this solution, however, we are quite free to add a gradient of any function because the curl of the gradient of any scalar is zero. It so happens that we can easily surmise what we should add, because the part to be added must reduce to $-\text{grad } V$ when there are no varying currents. In such cases both $\partial \boldsymbol{H}/\partial t=0$ and $\partial \boldsymbol{A}/\partial t=0$. The total electric field is thus

$$\boldsymbol{E}=-\frac{1}{c}\frac{\partial \boldsymbol{A}}{\partial t}-\text{grad } V \qquad (27)$$

It is well to stop for a moment and inquire a bit farther into the nature of term $\boldsymbol{E}'=-(1/c)(\partial \boldsymbol{A}/\partial t)$. Let us consider two closed circuits S_1 and S_2 in Figure 9. Let us assume that current *I* is flowing in circuit S_1. The vector potential of current *I* is

$$\boldsymbol{A}=\frac{1}{c}\oint_{S_1}\frac{[\boldsymbol{I}]}{r}dS_1 \qquad (28)$$

If the frequency we are dealing with is sufficiently low, the dimensions of circuits S_1, S_2, and of the distances between them are all small in comparison with the wave length. It will therefore make no substantial difference whether we use *I* at time *t* or at time $t-r/c$. Besides, current *I* will be substantially constant around S_1. Accordingly

$$\boldsymbol{A}=\frac{1}{c}\oint_{S_1}\frac{\boldsymbol{I}}{r}dS_1 \qquad (29)$$

and

$$\boldsymbol{E}'=-\frac{1}{c}\frac{\partial \boldsymbol{A}}{\partial t}=-\frac{\partial}{\partial t}\left\{\frac{1}{c^2}\oint_{S_1}\frac{\boldsymbol{I}}{r}dS_1\right\} \qquad (30)$$

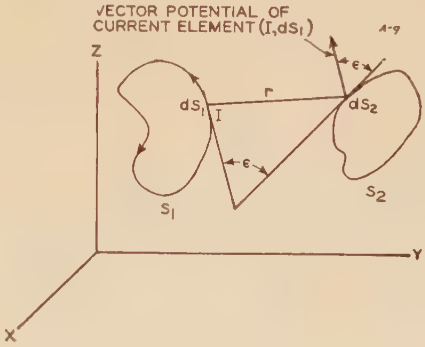


Figure 9. Coupled circuits

Current I flowing in closed circuit S_1 induces electromotive force in closed circuit S_2

This $\boldsymbol{E}'$ is, of course, a vector. If we wish to calculate the component of $\boldsymbol{E}'$ in any direction, for example, in the direction of element dS_2 of S_2, we may, if we so desire, project each individual element $d\boldsymbol{E}'$ on direction of dS_2 by writing $I \cos \epsilon$ in place of **I** where $\cos \epsilon$ is the angle between **I** and dS_2 (see Figure 9). The component of $\boldsymbol{E}'$ in the direction of dS_2 is thus

$$E'_{ds_2}=-\frac{\partial}{\partial t}\left\{\frac{1}{c^2}\oint_{S_1}\frac{I\cos\epsilon}{r}dS_1\right\}=-\frac{\partial I}{\partial t}\left[\frac{1}{c^2}\oint_{S_1}\frac{\cos\epsilon}{r}dS_1\right]$$

where *I* is the scalar magnitude of **I**. Since $E'_{ds_1}dS_2$ is the electromotive force induced in element dS_2, it is clear that $\left[\frac{1}{c^2}\oint\frac{\cos\ \epsilon}{r}dS_1\right]dS_2$ is the mutual inductance between circuit S_1 and element dS_2. By integrating with respect to dS_2 around circuit S_2, we find the total electromotive force induced in this circuit:

$$\text{emf} = -\frac{\partial I}{\partial t}\left\{\frac{1}{c^2}\oint_{S_2}\oint_{S_1}\frac{\cos\epsilon}{r}\,dS_1dS_2\right\} = -\frac{\partial I}{\partial t}M \qquad (31)$$

where

$$M = \frac{1}{c^2}\oint_{S_2}\oint_{S_1}\frac{\cos\epsilon}{r}dS_1dS_2 \qquad (32)$$

The quantity M is the mutual inductance between circuits S_1 and S_2.

It is thus clear that term $-(1/c)(\partial \boldsymbol{A}/\partial t)$ in equation 27 replaces the familiar $-(\partial I/\partial t)\ M$ of low-frequency equations. This term $-(1/c)(\partial \boldsymbol{A}/\partial t)$ reduces to $-(\partial I/\partial t)M$ when frequency is so low that the magnitude of current around the circuit is substantially constant, and the time of propagation is small in comparison with the period.

The inquiry into the nature of $-(1/c)(\partial \boldsymbol{A}/\partial t)$ has taken us a bit off our path, and it is well now to take stock of the results. We have shown that, when the currents and charges are varying rapidly with time, the magnetic field

$$\boldsymbol{H} = \text{curl } \boldsymbol{A} \qquad (17)$$

where

$$\boldsymbol{A} = \frac{1}{c}\int\int\int\frac{[\boldsymbol{i}]}{r}dv \qquad (18)$$

and that the electric field

$$\boldsymbol{E} = -\frac{1}{c}\frac{\partial \boldsymbol{A}}{\partial t} - \text{grad } V \qquad (27)$$

where

$$V = \int\int\int\frac{[\rho]}{r}dv \qquad (19)$$

Before we apply these equations to some examples which illustrate their use, it is well to add a word of caution. It may appear from inspection of these equations that we are free to make any assumptions whatsoever in regard to values of $\boldsymbol{i}$ and ρ, however fancy these assumptions might be. This is not true, for $\boldsymbol{i}$ and ρ must obey the continuity equation. This equation is

$$\frac{\partial i_x}{\partial x'} + \frac{\partial i_y}{\partial y'} + \frac{\partial i_z}{\partial z'} = -\frac{\partial \rho}{\partial t} \qquad (33)$$

or in vector notation

$$\text{div } \boldsymbol{i} = -\frac{\partial \rho}{\partial t} \qquad (34)$$

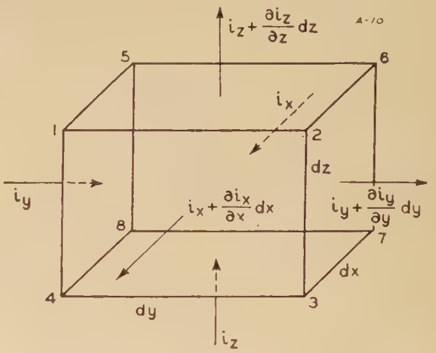
The meaning of this equation becomes clear if both sides of it are multiplied by $dx'dy'dz'$, and the physical significance of the terms is visualized with the aid of Figure 10.

$$\left(\frac{\partial i_x}{\partial x'}dx'\right)dy'dz' + \left(\frac{\partial i_y}{\partial y'}dy'\right)dx'dz' + \left(\frac{\partial i_z}{\partial z'}dz'\right)dx'dy' = -\frac{\partial \rho}{\partial t}dx'dy'dz' \qquad (35)$$

The first term $\left(\frac{\partial i_x}{\partial x'}dx'\right)dy'dz' = \left(i_xdz'dy' + \frac{\partial i_x}{\partial x}dz'dy'\right) - i_xdz'dy'$

is equal to the difference between the current which flows out of volume $dx'dy'dz'$ through face 1, 2, 3, 4, and the current which flows into $dx'dy'dz'$ through face 5, 6, 7, 8. Similarly, the other two terms on the left-hand side represent the differences between the currents flowing *out of* and flowing *into* the other pairs of faces of volume $dx'dy'dz'$. The entire left-hand side of equation 35 represents the difference between the current leaving the volume and the current entering this volume. The difference between these two currents can be made up only by depleting the total charge $\rho dx'dy'dz'$ within the volume. Equation 33 states this fact in mathematical terms.

Figure 10. Used in deriving equation 22


$i_z + \frac{\partial i_z}{\partial z}dz$
A-10
5
6
i_x
1
2
dz
i_y
$i_x + \frac{\partial i_x}{\partial x}dx$
$i_y + \frac{\partial i_y}{\partial y}dy$
8
7
dx
4
dy
3
i_z

If our assumptions in regard to $\boldsymbol{i}$ and ρ contradict equation 33, we have an impossible combination of $\boldsymbol{i}$ and ρ, and we should not be surprised to end up with $\boldsymbol{E}$ and $\boldsymbol{H}$ which are incompatible with each other.

The same equation can be approached from another point of view. At any point in space $\boldsymbol{E}$ and $\boldsymbol{H}$ must satisfy Maxwell's equations: [1,5,6,7,8]

$$\text{curl } \boldsymbol{E} = -\frac{1}{c}\frac{\partial \boldsymbol{H}}{\partial t} \quad (\boldsymbol{a}) \qquad\qquad \text{div } \boldsymbol{H} = 0 \quad (\boldsymbol{b})$$

$$\text{curl } \boldsymbol{H} = +\frac{1}{c}\frac{\partial \boldsymbol{E}}{\partial t} \quad (\boldsymbol{d}) \qquad\qquad \text{div } \boldsymbol{E} = 0 \quad (\boldsymbol{c})$$

We have seen already that $\boldsymbol{E}$ is such that equation a is satisfied. In fact, this equation was used in evaluating $\boldsymbol{E}$. Equation b is satisfied by $\boldsymbol{H}$ because $\boldsymbol{H} = \text{curl } \boldsymbol{A}$ and the divergence of the curl of any vector is zero. If our values of $\boldsymbol{E}$ and $\boldsymbol{H}$ are substituted into equation c it reduces to

$$\frac{\partial}{\partial t}\left(-\frac{1}{c}\text{div } \boldsymbol{A}\right) - \nabla^2 V = 0 \qquad (36)$$

where

$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2}$$

Since $[\rho] = f(x', y', z', (t - r/c)]$, the quantity $u = [\rho]/r$

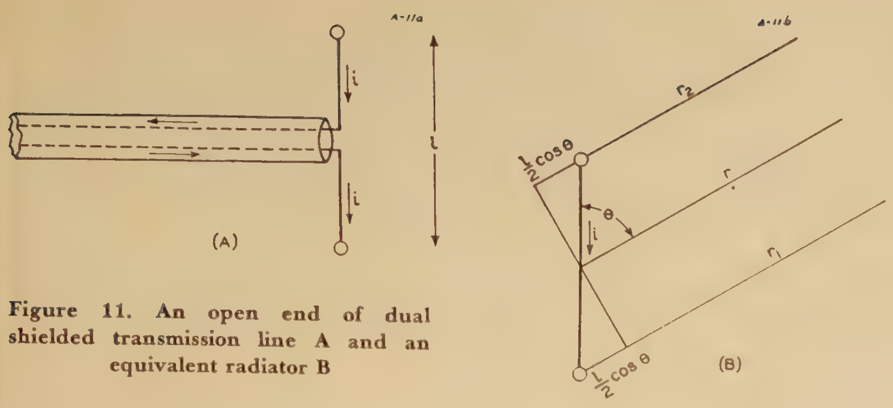


Figure 11. An open end of dual shielded transmission line A and an equivalent radiator B

satisfies the following equation $\nabla^2 U - (1/c^2)(\partial^2 u/\partial t^2) = 0$. The integral $V = \int\int\int([\rho]/r)dv$, which is a sum of the u's, satisfies a similar equation

$$\nabla^2 V - \frac{1}{c^2}\frac{\partial^2 V}{\partial t^2} = 0 \qquad (37)$$

By substituting the value of $\nabla^2 V$ from equation 37 into 36, we find that

$$\frac{\partial}{\partial t}\left(-\frac{1}{c}\,\text{div}\ \boldsymbol{A}\right) - \frac{1}{c^2}\frac{\partial^2 V}{\partial t^2} = 0 \qquad (38)$$

By integrating equation 38 with respect to t, we get

$$-\frac{1}{c}\ \text{div}\ \boldsymbol{A} - \frac{1}{c^2}\frac{\partial V}{\partial t} = \varphi(x, y, z) \qquad (39)$$

Next, we substitute $\boldsymbol{H} = \text{curl}\ \boldsymbol{A}$, $\boldsymbol{E} = -(1/c)(\partial \boldsymbol{A}/\partial t) - \text{grad} V$ into equation d. Since $\boldsymbol{i} = \boldsymbol{F}[x', y', z', t-(r/c)]$, the quantity $v = ([\boldsymbol{i}]/r)$ satisfies an equation similar to equation 37 and so does the integral $\boldsymbol{A} = (1/c) \times \int\int\int([\boldsymbol{i}]/r)dv$, that is,

$$\nabla^2 \boldsymbol{A} - \frac{1}{c^2}\frac{\partial \boldsymbol{A}^2}{\partial t^2} = 0 \qquad (40)$$

Since

$$\text{curl}(\text{curl}\ \boldsymbol{A}) = -\nabla^2 \boldsymbol{A} + \text{grad}\ (\text{div}\ \boldsymbol{A})$$

we find that equation d reduces to

$$-\nabla^2 \boldsymbol{A} + \text{grad}\ (\text{div}\ \boldsymbol{A}) = -\frac{1}{c^2}\frac{\partial^2 \boldsymbol{A}}{\partial t^2} - \text{grad}\left(\frac{1}{c}\frac{\partial V}{\partial t}\right)$$

which in view of equation 40 becomes

$$\text{grad}\left(\text{div}\ \boldsymbol{A} + \frac{1}{c}\frac{\partial V}{\partial t}\right) = 0 \qquad (41)$$

By comparing equation 41 with equation 39 we see that grad $\varphi(x, y, z) = 0$, that is, $\partial\varphi/\partial x = 0$, $\partial\varphi/\partial y = 0$, $\partial\varphi/\partial z = 0$. This is possible only when $\varphi = \text{a constant} = k$. At very large distances from the radiator $\boldsymbol{A} = 0$, $V = 0$, also div$\boldsymbol{A} = 0$ and $\partial v/\partial t = 0$. Therefore, the left-hand side of equation 39 which we have just proved to be equal to k is zero. It follows that

$$\text{div}\ \boldsymbol{A} + \frac{1}{c}\frac{\partial V}{\partial t} = 0 \qquad (42)$$

at all points in space.* When values of $\boldsymbol{A}$ and V are substituted, equation 42 reduces to a relation between $\boldsymbol{i}$ and ρ. After some manipulation (which will not be reproduced here) equation 42 reduces to[6]

$$\text{div}\ \boldsymbol{i} + \frac{\partial \rho}{\partial t} = 0 \qquad (34)$$

plus the requirement that the current is not allowed either to enter or leave the volume over which the integral $(1/c)\int\int\int([\boldsymbol{i}]/r)dv$ is taken. This condition is obviously satisfied when the integral is extended over all regions where $\boldsymbol{i} \neq 0$, which is exactly what we agreed to do. This limitation is therefore of interest only when one is calculating the field of a part of a conductor. In such cases the limitation may be side-stepped by providing assumed charges into which or out of which the current is allowed to flow, and by adding the potential of these charges to $\int\int\int([\rho]/r)dv$ or by extending this integral itself over these charges.

We shall now illustrate the use of equations 17, 18, 27, and 19 by applying them to a simple example.

In Figure 11 is shown an "open end" of a dual shielded transmission line. The two conductors of the transmission line are bent at right angles and are provided with small spherical end condensers. This somewhat unusual arrangement was chosen in order that the integrations which we shall have to perform may be as simple as possible.

It will be assumed that the spacing between the transmission-line conductors is very small in comparison with the distance l between the two end capacitors and that the distance l itself is small in comparison with the wave length. Under these conditions the field produced by one conductor of the dual transmission line will be canceled by the field of the other conductor, and arrangement A will be equivalent to B, in that both will produce the same field in the surrounding space.

Since l is very small in comparison with the wave length, current I is very nearly constant along the wire joining the two capacitors. If the charges on the end capacitors at time t are q and $-q$, currents I and q are such that

$$I = -\frac{\partial q}{\partial t} \qquad (43)$$

This equation takes the place of

$$\text{div}\ \boldsymbol{i} = \frac{\partial i_z}{\partial z} = -\frac{\partial \rho}{\partial t}$$

because we are assuming that the current at the end capacitors is changing abruptly from I to 0 so that

$$\frac{\partial i_z}{\partial z}dv = I = -\frac{\partial \rho}{\partial t}dv = -\frac{\partial q}{\partial t}$$

---

* It can be shown that equation 42 holds good even within the conductor.

The scalar potential at a point Q in space is

$$V=\int\int\int\frac{[\rho]}{r}dv=\frac{[q]}{r_1}+\frac{[-q]}{r_2} \tag{44}$$

where r_1 and r_2 are the distances between charges q and $-q$ and the point of observation Q. The components of the vector potential are

$$Az=\frac{1}{c}\int\int\int\frac{[i]}{r}dv=\frac{1}{c}\int_0^l\frac{[I]}{r}dz=\frac{1}{c}\frac{[I]l}{r} \tag{45}$$

$$A_x=0 \qquad A_y=0$$

provided, of course, that r is assumed to be large in comparison with l. When $I=I_0 \sin \omega t$, the charge q is

$$q=-\int Idt=\frac{I_0}{\omega}\cos \omega t$$

Accordingly, from equations 45 and 44

$$A_z=\frac{1}{c}\frac{I_0 \sin \omega\left(t-\frac{r}{c}\right)}{r}l \tag{46}$$

$$V=\frac{\frac{I_0}{\omega}\cos \omega\left(t-\frac{r_1}{c}\right)}{r_1}-\frac{\frac{I_0}{\omega}\cos \omega\left(t-\frac{r_2}{c}\right)}{r_2} \tag{47}$$

When l is very small in comparison with r and with λ

$$r_1=r+\frac{l}{2}\cos\theta, \qquad r_2=r-\frac{l}{2}\cos\theta, \qquad \cos\left(\frac{\omega l}{2e}\cos\theta\right)=1,$$

$$\sin\left(\frac{\omega l}{2c}\cos\theta\right)=\frac{\omega l}{2c}\cos\theta \text{ (see Figure 11)}$$

and equation 47 becomes

$$V=-\frac{I_0}{\omega}\left\{\frac{\cos \omega\left(t-\frac{r}{c}\right)}{r^2}l\cos\theta-\frac{\sin \omega\left(t-\frac{r}{c}\right)}{r}\frac{\omega l}{c}\cos\theta\right\} \tag{48}$$

The components of the magnetic field are $H_z=\frac{\partial A_y}{\partial x}-\frac{\partial A_x}{\partial y}=0$

$$H_y=\frac{\partial A_x}{\partial z}-\frac{\partial A_z}{\partial x}=-\frac{\partial A_z}{\partial x}=-\frac{\partial}{\partial x}\left\{\frac{I_0 \sin \omega\left(t-\frac{r}{c}\right)}{cr}l\right\}$$

$$H_x=\frac{\partial A_z}{\partial y}-\frac{\partial A_y}{\partial z}=+\frac{\partial A_z}{\partial y}=\frac{\partial}{\partial y}\left\{\frac{I_0 \sin \omega\left(t-\frac{r}{c}\right)}{cr}l\right\}$$

Hence

$$H_y=\left[\frac{I_0l}{cr^2}\sin \omega\left(t-\frac{r}{c}\right)+\frac{\omega}{c^2}\frac{I_0l}{r}\cos \omega\left(t-\frac{r}{c}\right)\right]\frac{x}{r} \tag{49}$$

$$H_x=\left[-\frac{I_0l}{cr^2}\sin \omega\left(t-\frac{r}{c}\right)-\frac{\omega}{c^2}\frac{I_0l}{r}\cos \omega\left(t-\frac{r}{c}\right)\right]\frac{y}{r} \tag{50}$$

The total H is

$$H=\sqrt{H_x^2+H_y^2}=\left[\frac{I_0l}{cr^2}\sin \omega\left(t-\frac{r}{c}\right)+\frac{\omega}{c^2}\frac{I_0l}{r}\cos \omega\left(t-\frac{r}{c}\right)\right]\times\frac{\sqrt{x^2+y^2}}{r} \tag{51}$$

The components of the electric field $\boldsymbol{E}$ in rectangular co-ordinates are not particularly convenient to deal with. It will be preferable to calculate the components of $\boldsymbol{E}$ in spherical co-ordinates. For this purpose it is necessary to find A_ϕ, A_r, and A_θ. Since $A_x=0$, $A_y=0$, and, since A_z has no component in direction of small circles, $A_\varphi=0$. The other two components A_θ and A_r are obtained by projecting A_z on r and on the tangent to a great circle $r=$const, $\varphi=$const. The angle between A_z and r is θ. The angle between A_z and the tangent is $\pi/2-\theta$. Therefore

$$A_r=A_z\cos\theta \tag{52}$$

and

$$A_\theta=-A_z\cos\left(\frac{\pi}{2}-\theta\right)=-A_z\sin\theta \tag{53}$$

The line element in spherical co-ordinates is given by

$$ds^2=dr^2+r^2d\theta^2+(r\sin\theta)^2d\varphi^2$$

The three components of gradient are therefore

$$\left.\begin{aligned}\text{grad}_r\, V&=\frac{\partial V}{\partial r}\\ \text{grad}_\theta\, V&=\frac{\partial V}{r\partial\theta}\\ \text{grad}_\varphi\, V&=\frac{1}{r\sin\theta}\frac{\partial V}{\partial\varphi}\end{aligned}\right\} \tag{54}$$

The last component is equal to zero, because V does not depend on φ. From equation 27

$$E_r=-\frac{1}{c}\frac{\partial Ar}{\partial t}-\text{grad}_r\, V$$

This equation, in view of equations 48, 54, and 52, becomes

$$E_r=-\frac{1}{c}\frac{\partial}{\partial t}\left[\frac{\frac{1}{c}I_0\sin \omega\left(t-\frac{r}{c}\right)}{r}l\cos\theta\right]+$$

$$\frac{\partial}{\partial r}\frac{I_0}{\omega}\left[\frac{\cos \omega\left(t-\frac{r}{c}\right)}{r^2}l\cos\theta-\frac{\sin \omega\left(t-\frac{r}{c}\right)}{r}\frac{\omega l}{c}\cos\theta\right]$$

$$=-\frac{2I_0l}{\omega}\frac{\cos\theta}{r^2}\left[\frac{1}{r}\cos \omega\left(t-\frac{r}{c}\right)-\frac{\omega}{c}\sin \omega\left(t-\frac{r}{c}\right)\right] \tag{55}$$

Similarly we find that

$$E_\theta=-\frac{1}{c}\frac{\partial A_\theta}{\partial t}-\text{grad}_\theta\, V$$

$$=-\frac{1}{c}\frac{\partial}{\partial t}\left[-\frac{1}{c}\frac{I_0\sin \omega\left(t-\frac{r}{c}\right)}{r}l\sin\theta\right]-$$

$$\frac{1}{r}\frac{\partial}{\partial\theta}\left\{-\frac{I_0}{\omega}\left[\frac{\cos \omega\left(t-\frac{r}{c}\right)}{r^2}l\cos\theta-\frac{\sin \omega\left(t-\frac{r}{c}\right)}{r}\frac{\omega l}{c}\cos\theta\right]\right\}$$

$$E_\theta=-\frac{I_0l}{\omega}\frac{\sin\theta}{r}\left[\left(\frac{1}{r^2}-\frac{\omega^2}{c^2}\right)\cos \omega\left(t-\frac{r}{c}\right)-\frac{\omega}{cr}\sin \omega\left(t-\frac{r}{c}\right)\right] \tag{56}$$

An examination of equations 51 and 56 reveals that both H and E_θ contain terms which vary as $1/r$. E_r has no such terms. At a large distance from the radiator all other terms which vary as $1/r^2$ and $1/r^3$ become negligible in comparison with the terms which vary as $1/r$ and

$$\text{Total } H = H_\varphi = \frac{\omega}{c^2}\frac{I_0 l}{r} \cos \omega\left(t - \frac{r}{c}\right) \sin\theta \tag{57}$$

$$\text{Total } E = E_\theta = \frac{\omega}{c^2}\frac{I_0 l}{r} \cos \omega\left(t - \frac{r}{c}\right) \sin\theta \tag{58}$$

$$\left.\begin{aligned} E_r &= 0 \\ E_\varphi &= 0 \end{aligned}\right\} \tag{59}$$

The $1/r$ terms in both H and E_θ contain ω in the numerator. These terms may be dropped when ω is very small. The terms which remain in this case are

$$H = \frac{I_0 l}{cr^2} \sin\theta \cdot \sin \omega t = \frac{I_0 l}{cr^2} \sin\theta$$

$$E_\theta = -\frac{I_0 l}{\omega}\frac{\sin\ \theta}{r^3} \cos \omega t = -\frac{ql}{r^3} \sin\theta$$

This value of H follows at once from the Biot-Savart law for steady or slowly varying currents. The value of E_θ is the familiar component of the field of two charges q and $-q$ separated by a very small distance l.

The fact that at a large distance from the radiator both $\boldsymbol{H}$ and $\boldsymbol{E}$ vary as $1/r$ has some very important consequences. It is well known that the Poynting vector[1] $\boldsymbol{P} = (c/4\pi)\boldsymbol{E}\times\boldsymbol{H}$ represents the power transported by the field through a unit area placed at right angles to vector $\boldsymbol{P}$. Vector $\boldsymbol{P}$ is at right angles to both $\boldsymbol{H}$ and $\boldsymbol{E}$, and its magnitude is $(c/4\pi)EH \sin\delta$, where δ is the angle between vectors $\boldsymbol{H}$ and $\boldsymbol{E}$. When $\boldsymbol{H}$ and $\boldsymbol{E}$ are at right angles with respect to each other, $\sin\delta = 1$. By substituting the values of H and E from equations 57 and 58 into the expression for P, it is found that

$$P = \frac{c}{4\pi}\left(\frac{\omega}{c^2}\right)^2\left(\frac{I_0 l}{r}\right)^2 \sin^2\theta \cos^2 \omega\left(t - \frac{r}{c}\right) \tag{60}$$

If the radiator is surrounded by a sphere of large radius r, the power which is transported through an element $dS = rd\theta \cdot r \sin\theta d\varphi$ of surface is

$$Pds = Pr^2 d\theta \sin\theta d\varphi$$

The total power which goes through the sphere is

$$W = \frac{c}{4\pi}\left(\frac{\omega}{c^2}\right)^2 (I_0 l)^2 \cos^2 \omega\left(t - \frac{r}{c}\right) \int_0^{2\pi} d\varphi \int_0^{\pi} \sin^3\theta d\theta$$

$$= \frac{2c}{3}\left(\frac{\omega l}{c^2} I_0\right)^2 \cos^2 \omega\left(t - \frac{r}{c}\right) \tag{61}$$

This is a pulsating quantity which is always greater than zero. The average value of

$$\cos^2 \omega\left(t - \frac{r}{c}\right)$$

per cycle, also per unit of time, is

$$\frac{1}{2\pi}\int_0^{2\pi} \cos^2 x dx = {}^1/_2$$

consequently, the average value of W is

$$\overline{W} = \frac{1}{3c}\left(\frac{l\omega}{c}\right)^2 I_0^2 = \frac{1}{3c}\left(\frac{2\pi l}{\lambda}\right)^2 I_0^2 \tag{62}$$

This is the power which goes through the surface of any sphere, or for that matter, any closed surface around the radiator.

The law of conservation of energy demands that equal power be delivered to the radiator. In order that this may be the case, the current at some point or points of the radiator must flow against an electromotive force which has an inphase component. The value of this counterelectromotive force is proportional to the current, and its inphase component may be represented by the product of current times resistance. Resistance of this nature is usually called radiation resistance. The value of this resistance may be calculated readily when the power W radiated by the radiator is known. If I_0 is the peak value of the current, the rms is $I_0/\sqrt{2}$, and the power delivered by the current into a resistance R is $R(I_0/\sqrt{2})^2$. This power must be equal to the radiated power $\overline{W}$. Thus we may write

$$\left(R\frac{I_0}{\sqrt{2}}\right)^2 = \overline{W} = \frac{1}{3}\frac{1}{c}\left(\frac{2\pi l}{\lambda}\right)^2 I_0^2$$

$$R = \frac{2}{3}\frac{1}{c}\left(\frac{2\pi l}{\lambda}\right)^2 \text{ in electrostatic units}$$

Since one electrostatic unit $= 9\times10^{11}$ ohms and $c = 3\times10^{10}$ it follows that

$$R = \frac{60}{3}\times\left(\frac{2\pi l}{\lambda}\right)^2 = 80\pi^2\left(\frac{l}{\lambda}\right)^2 \text{ohms}$$

In order to illustrate some additional features of the method, it will be applied to the case of a thin wire a half wave length long. In this case it is again necessary to assume the distribution of current along the wire. When the wire is very thin, experiments show that the current distribution is very nearly sinusoidal, so that current I at any point along the half-wave is

$$I = I_0 \sin kz \cdot \sin \omega t$$

From the equation of continuity

$$\frac{\partial I}{\partial z} + \frac{\partial \bar{\rho}}{\partial t} = 0$$

It follows that the charge density $\bar{\rho}$ (charge per unit length) is given by

$$\bar{\rho} = -\frac{k}{\omega} I_0 \cos kz \cdot \cos \omega t$$

When the half-wave wire is placed along the z axis with one end of the wire at the origin of co-ordinates, the components of the vector potential are

$$A_z=\frac{1}{c}\int_0^l \frac{I_0 \sin kz\cdot\sin\omega\left(t-\frac{r}{c}\right)}{r}dz$$

$$A_x=0 \qquad A_y=0$$

The scalar potential is

$$V=\frac{1}{c}\int_0^l -\frac{kI_0}{\omega}\frac{\cos kz\cdot\cos\omega\left(t-\frac{r}{c}\right)}{r}dz$$

These integrations are fairly lengthy and are not of much interest.[6] They will, therefore, be omitted. The components of H are

$$H_r=0,\quad H_\varphi=0,$$

$$H_\theta=\frac{I_0}{cr\sin\theta}\left\{\sin\omega\left(t-\frac{r_1}{c}\right)-\sin\omega\left(t-\frac{r_2}{c}\right)\right\}$$

in which r_1 and r_2 are the distances from the two ends of the wire to the point at which H is observed. This equation, as well as the companion equations for the components of E, is valid up to the surface of the wire. At large distances from the wire $E_r=0$ and

$$E_\theta=H_\varphi=\frac{2I_0}{rc}\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

The total radiated power is calculated as in the previous example

$$P=\frac{c}{4\pi}\times\frac{1}{2}\times\int_0^{2\pi}d\varphi\int_0^{\pi}\left[\frac{2I_0}{rc}\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]^2 r^2\sin\theta d\theta$$

$$=\frac{I_0^2}{c}(1.22)$$

The radiation resistance R_0 is found by equating

$$R_0\left(\frac{I_0}{\sqrt{2}}\right)^2=P=\frac{I_0^2}{c}(1.22)$$

from which

$$R_0=\frac{1}{c}\times2\times1.22=30\times2\times1.22=73.5 \text{ ohms}$$

This radiation resistance is with reference to the current at the center of the half-wave wire. It is sometimes convenient to use as reference current I_1 at some other point $Z=Z_1$ along the wire. The radiation resistance R_1 with reference to this current must be such that

$$\left(\frac{I_1}{\sqrt{2}}\right)^2R_1=\left(\frac{I_0}{\sqrt{2}}\right)^2R_0$$

MODIFICATION OF METHOD 1

Some authors prefer to express all components of H and E in terms of one single vector Π which is called the Hertzian (radiation) vector. This procedure is substantially equivalent to method 1 as explained on the preceding pages.

Let current density $i=\partial P/\partial t$ then

$$A=\frac{1}{c}\iiint\frac{[i]}{r}dv$$

$$=\frac{1}{c}\iiint\frac{\left[\frac{\partial P}{\partial t}\right]dv}{r}$$

$$=\frac{1}{c}\frac{\partial}{\partial t}\iiint\frac{[P]}{r}dv$$

$$=\frac{1}{c}\frac{\partial\Pi}{\partial t}$$

where

$$\pi=\iiint\frac{[P]}{r}dv \tag*{63)}$$

$$H=\text{curl } A=\frac{1}{c}\text{ curl}\left(\frac{\partial\Pi}{\partial t}\right) \tag{64}$$

Since

$$\text{div } A+\frac{1}{c}\frac{\partial V}{\partial t}=0 \tag{42}$$

$$\frac{\partial}{\partial t}\left(\text{div }\frac{1}{c}\Pi\right)+\frac{1}{c}\frac{\partial V}{\partial t}=0$$

and

$$V=-c\text{ div}\left(\frac{1}{c}\Pi\right)+\psi(x,y,z)$$

Function $\psi(x,y,z)$ is independent of time and represents the potential of static charges. When there are no static charges

$$E=-\frac{1}{c^2}\frac{\partial^2\Pi}{\partial t^2}+\text{grad (div }\Pi) \tag{65}$$

This procedure avoids the necessity of solving the equation of continuity for ρ and then calculating the scalar potential V. The equation of continuity is solved indirectly and once and for all when the value of V is expressed in terms of Π by solving

$$\text{div } A+\frac{1}{c}\frac{\partial V}{\partial t}=0$$

which is substantially equivalent to the continuity equation 34.

The second part of this article discussing method 2 is scheduled to appear in a subsequent issue.

REFERENCES

1. Ultrashort Electromagnetic Waves—I. Electromagnetic Theory, **Ernst Weber.** *Electrical Engineering*, volume 62, March 1943, pages 103–12.

2. Ultrashort Electromagnetic Waves—II. Transmission-Line Theory, **John R. Ragazzini.** *Electrical Engineering*, volume 62, April 1943, pages 159–67.

3. Ultrashort Electromagnetic Waves—III. Generation, **I. E. Mouromtseff.** *Electrical Engineering*, volume 62, May 1943, pages 206–15.

4. Ultrashort Electromagnetic Waves—IV. Guided Propagation, **S. A. Schelkunoff.** *Electrical Engineering*, volume 62, June 1943, pages 235–46.

5. Fundamentals of Electric Waves (book), **H. H. Skilling.** John Wiley and Sons, 1942.

6. Electromagnetic Theory (book), **J. A. Stratton.** McGraw-Hill Book Company, Inc., 1941.

7. Microwave Transmission (book), **J. C. Slater.** McGraw-Hill Book Company, Inc., 1941.

8. Electromagnetic Waves (book), **S. A. Schelkunoff.** D. Van Nostrand Company, 1943.

INSTITUTE ACTIVITIES

Officers for 1943–44 Announced at Cleveland Meeting

Officers of the Institute for the year beginning August 1, 1943, were announced in the report of the committee of tellers presented at the annual meeting during the recent national technical meeting at Cleveland, Ohio. The new officers are:

President: Nevin E. Funk, vice-president in charge of engineering, Philadelphia (Pa.) Electric Company.

Vice-Presidents: W. E. Wickenden, president of the Case School of Applied Science, Cleveland, Ohio (District 2, Middle Eastern); C. W. Ricker, head of the school of electrical engineering, Tulane University, New Orleans, La. (District 4, Southern); L. A. Bingham, assistant professor in electrical engineering, University of Nebraska, Lincoln (District 6, North Central); W. J. Gilson, general manager, Eastern Power Devices, Ltd., Toronto, Ont. (District 10, Canada); J. M. Gaylord, chief electrical engineer, Metropolitan Water District of Southern California, Los Angeles (District 8, Pacific).

Directors: S. H. Mortensen, chief electrical engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.; C. W. Mier, engineer, Southwestern Bell Telephone Company, Dallas, Tex.; C. M. Laffoon, engineering manager of the a-c-generator engineering department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. (re-elected).

Treasurer: W. I. Slichter, professor emeritus of electrical engineering, Columbia University, New York, N. Y. (re-elected).

The board of directors for the administrative year beginning August 1, 1943, will consist of the foregoing elected officers and the following holdover officers:

H. S. Osborne, New York, N. Y. (*retiring president*); D. C. Prince, Schenectady, N. Y. (*junior past president*); K. B. McEachron, Pittsfield, Mass.; C. R. Jones, New York, N. Y.; A. G. Dewars, Minneapolis, Minn.; E. T. Mahood, Kansas City, Mo.; E. W. Schilling, Bozeman, Mont. (*vice-presidents*); T. F. Barton, New York, N. Y.; M. S. Coover, Ames, Iowa,; R. G. Warner, New Haven, Conn.; L. R. Gamble, Spokane, Wash.; T. G. LeClair, Chicago, Ill.; F. R. Maxwell, Jr., Pensacola, Fla.; K. L. Hansen, Milwaukee, Wis.; W. B. Morton, Philadelphia, Pa.; L. R. Smith, Newark, N. J. (*directors*).

A detailed report of the national technical meeting at Cleveland is scheduled to appear in the August issue.

Future AIEE Meetings

National Technical Meeting
Salt Lake City, Utah, September 2–4, 1943

Southern District Meeting
Roanoke, Va., November 16–18, 1943

Revised Standards Approved at Executive Committee Meeting

The executive committee of the American Institute of Electrical Engineers met at Institute headquarters, New York, May 27, 1943, in lieu of the regular May meeting of the board of directors.

Present: Members of the committee—Chairman H. S. Osborne and C. R. Jones, New York, N. Y.; David C. Prince and W. I. Slichter, Schenectady, N. Y.; R. W. Sorensen, Pasadena, Calif.; R. G. Warner, New Haven, Conn. Other members of the board of directors—Vice-President C. A. Powel, East Pittsburgh, Pa.; Directors T. G. LeClair, Chicago, Ill., and W. Ralph Smith, Newark, N. J. By invitation—Vice-Chairman George R. Canning of the Cleveland national technical meeting committee for the period of discussion of plans for that meeting, and National Secretary H. H. Henline.

Executive committee actions on applications were reported and confirmed, as follows: As of March 22, 1943, 8 applicants were transferred to the grade of Fellow and 35 to the grade of Member, 41 applicants were elected to the grade of Member and 195 to the grade of Associate, and 286 Students were enrolled; as of April 9, 1943, 4 applicants were transferred to the grade of Fellow and 19 to the grade of Member, 434 applicants were elected to the grade of Associate, and 68 Students were enrolled.

Also reported and approved was approval by the executive committee, upon recommendation of the standards committee, of: Revision of the American Standard, "Letter Symbols for Heat and Thermodynamics Including Heat Flow," developed by sectional committee *Z*10 on Letter Symbols and Abbreviations for Science and Engineering, to supersede the American Tentative Standard of the same name published in 1931; War Emergency Modification of AIEE Standard 45, "Recommended Practice for Electrical Installations on Shipboard," prepared by the committee on marine transportation, for publication as a supplement to Standard 45 to apply for the war emergency only.

Recommendations adopted by the board of examiners at meetings on February 18, March 18, April 22, and May 20, 1943, were approved. The following actions were taken upon recommendation of the board of examiners: 6 applicants were transferred and one was re-elected to the grade of Fellow, 29 applicants were transferred and 49 were elected to the grade of Member, 310 were elected to the grade of Associate, and 312 Students were enrolled.

Disbursements were reported by the finance committee, and approved by the executive committee, as follows: February, $27,400.96; March, $32,797.61; April, $25,264.77; May, $28,328.00.

The annual report of the national treasurer for the fiscal year which ended April 30, 1943, was presented and accepted.

Approval was given for presentation at the annual meeting of the Institute on June 22 of the annual report of the board of directors for the fiscal year which ended April 30, 1943, prepared under the direction of the national secretary.

Dates and location of the Southern District technical meeting previously authorized to be held in Virginia in the fall of 1943 were approved, namely: November 16–18, Roanoke, Va. Decision was made to schedule a national technical meeting in New York, N. Y., January 24–28, 1944, and a national technical meeting in St. Louis, June 26–30, 1944.

Upon recommendation of the Sections committee, the following actions were taken:

A Dayton section was authorized, with territory comprising Preble, Montgomery, and Green Counties, Ohio (released by the Cincinnati Section), and Darke, Miami, Clark, Champaign, and Shelby Counties (released by the Columbus Section).

Unassigned counties in Nevada were assigned to Sections, as follows: Humboldt, Pershing, Churchill, Lander, and Esmeralda Counties to the San Francisco Section; Nye and Lincoln Counties to the Los Angeles Section; Elko, Eureka, and White-pine Counties to the Utah Section.

The name of the Saskatchewan Section was changed to Midwestern Canada Section, its territory to include the provinces of Manitoba and Alberta.

Members in Ottawa and vicinity were transferred from the Toronto Section to the Montreal Section, and that portion of the Province of Ontario east of a line drawn from Ottawa to Cornwall, formerly in the Toronto Section, was added to the territory of the Montreal Section.

The executive committee confirmed the endorsement by the committee on research of application to the Engineering Foundation for a grant for the year beginning October 1, 1943, to the Welding Research Council, for which the AIEE and the American Welding Society are joint sponsors.

The following actions were taken upon recommendation of the standards committee: Approved appointment of Herman Koenig as an AIEE representative on the sectional committee on electrical measuring instruments, *C*69, and D. E. Renshaw as representative and A. C. Muir as alternate on the sectional committee on safety rules for installing and using electrical equipment in coal mines, *M*2; approved for immediate publication a revision of AIEE Standard 19, "Oil Circuit Breakers," submitted by the committee on protective devices.

In accordance with section 37 of the constitution, H. H. Henline was reappointed national secretary of the Institute for the administrative year beginning August 1, 1943.

Approval was given to the publication by the Engineers' Council for Professional Development of a pamphlet outlining a plan of co-operation between the Engineering Council for Professional Development and local groups of the participating societies to further the objectives of ECPD.

The appointment by the president of the following committee of tellers to canvass and report on the ballots cast for the election of Institute officers was confirmed: L. B. Bogan, *chairman;* R. C. Darrow, M. L. Gardner, H. I. Perry, C. E. Scholz, Norman S. Spatz, and Otto E. Stamm.

F. Malcolm Farmer was nominated for re-election by the board of trustees of United Engineering Trustees, Inc., to the Engineering Foundation Board for the four-year term beginning in October 1943. H. B. Gear was reappointed a representative of the Institute on the Washington Award Commission for the two-year term beginning June 1, 1943.

Other matters were discussed, reference to which may be found in this or future issues of *Electrical Engineering.*

Contents of June 1943 Supplement Announced

The five remaining technical papers presented at the 1943 AIEE national winter technical meeting and not published in the monthly *Transactions* sections of *Electrical Engineering* will appear in the June 1943 "Supplement to Electrical Engineering—Transactions Section." The discussions of these papers and the discussions of the technical papers published in the January–June monthly sections will be included in the supplement. This will complete the publication of papers and discussions presented at the New York winter meeting.

Copies of the supplement will be mailed shortly to those who entered advance orders. Others may obtain copies at 50 cents each from the AIEE order department, 33 West 39th Street, New York 18, N. Y., as long as the limited supply lasts.

The following papers which have been abstracted in *Electrical Engineering* will be printed in the supplement:

43-23—Electrical Stability of Electrical Insulating Oils Under Limited Oxidation; *J. C. Balsbaugh (M '35), A. B. Assaf.* Abstracted in January 1943 issue, page 27.

43-12—Impulse and 60-Cycle Characteristics of Driven Grounds, III—Effect of Lead in Ground Installations; *P. L. Bellaschi (F '40), R. E. Armington (A '42).* Abstracted in January 1943 issue, page 30.

43-32—An Improved Axial Air-Blast Interrupter for Severe Operating Duty; *P. L. Taylor (A '27), H. W. Martin (A '40).* Abstracted in the January 1943 issue, page 32.

43-39—Staged-Fault Tests of Relaying and Stability on Kansas–Nebraska 270-Mile 154-Kv Interconnection; *C. W. Minard, R. B. Gow (A '35), W. A. Wolfe (M '36), E. A. Swanson.* Abstracted in January 1943 issue, page 33.

43-46—Field Disturbances Produced by Lightning; *G. D. McCann (A '38), D. E. Morgan (A '41).*

National and District Paper Prizes Awarded

The awards of the national prizes for the best papers presented during 1942 have been announced by P. L. Alger, chairman of the AIEE committee on award of Institute prizes. In choosing the papers the award committee had the assistance of the chairman of the technical committees in the various fields involved. As in 1940 and 1941 no award was made in the field of public relations and education because of lack of eligible papers in those categories. The prizes were presented, June 22, 1943, at the national technical meeting of the Institute at Cleveland, Ohio.

The final selections of the committee were:

Best Paper in Engineering Practice: Prize awarded to Herman Halperin (M '26) of the Commonwealth Edison Company, Chicago, Ill., for his paper, "Load Ratings of Cables—II," presented at the 1942 summer convention, June 22–26, and published in the 1942 *Transactions,* pages 930–42. Honorable mention was awarded to E. L. Harder (M '41), E. H. Klemmer (A '42), W. K. Sonnemann (M '43), and E. C. Wentz (M '42), of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., for their paper "Linear Couplers for Bus Protection," presented at the 1942 winter convention, January 26–30, and published in the 1942 *Transactions,* pages 241–48.

Best Paper in Theory and Research: Prize awarded to C. F. Wagner (F '40), G. D. McCann (A '38), and C. M. Lear, of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., for their paper "Shielding of Substations," presented at the 1942 winter convention, January 26–30, and published in the 1942 *Transactions,* pages 96–100. Honorable mention was awarded to R. C. Van Sickle (M '37) of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., for his paper "Transient Recovery Voltages and Circuit-Breaker Performance," presented at the 1942 summer convention, June 22–26, and published in the 1942 *Transactions,* pages 804–13.

Initial Paper: Prize awarded to T. D. Graybeal (A '38) of the University of California, Berkeley, for his paper, "Steady-State Theory of the Amplidyne Generator," presented at the 1942 summer convention, June 22–26, and published in the 1942 *Transactions,* pages 750–6. Honorable mention was awarded to D. E. Trucksess (M '40) of the Bell Telephone Laboratories, New York, N. Y., for his paper, "Regulated Rectifiers in Telephone Offices," presented at the 1942 summer convention, June 22–26, and published in the 1942 *Transactions,* pages 613–17.

Branch Paper: Prize awarded to Hugh Fleming (Enrolled Student) of Oregon State College, Corvallis, for his paper, "A Study of the Effect of High-Frequency Fields on Micro-Organisms," presented at a joint meeting of the Portland (Oreg.) Section and the Oregon State College Branch, May 16, 1942.

DISTRICT PRIZES

District prizes for AIEE papers have been announced by six Districts. The awards are for papers presented during 1942, except Branch papers, which were presented during the academic year ending June 30, 1942.

District 1

Prize for best paper was awarded to A. G. Conrad (M '40), Felix Zweig (A '42), and J. G. Clarke (A '41) for their paper, "Theory of the Brush-Shifting A-C Motor, Part IV," presented at the North Eastern District meeting, Schenectady, N. Y., April 29–May 1, 1942.

Prize for graduate student paper was awarded to B. P. Brown for his paper, "A New Transmitting Antenna for High-Definition Television," presented at the North Eastern District student convention, Rochester, N. Y., May 2, 1941.

Prize for Branch paper was awarded to S. B. Cohn (A '43) for his paper, "A New Automatic Radio Direction Finder," presented at the North Eastern District student convention, Schenectady, N. Y., May 1, 1942.

District 2

Prize for Branch paper was awarded to E. L. Bradford (A '43) for his paper, "Lightning Arresters for Distribution Systems," presented at a meeting of the Johns Hopkins University Branch, Baltimore, Md., December 11, 1941.

District 5

Prize for Branch paper was awarded to Sol London (A '43) for his paper, "Applications of Dimensional Analysis," presented at a meeting of the University of Iowa Branch, Iowa City, November 15, 1941.

District 6

Prize for Branch paper was awarded to Edward Edison (A '43) for his paper, "The Operation of Three-Phase Motors From a Single-Phase Supply," presented at the 15th annual District conference on student activities, Colorado State College, Fort Collins, April 17–18, 1942.

District 7

Prize for Branch paper was awarded to F. A. Collins (Enrolled Student) for his paper, "Separation of Core Losses," presented at a joint meeting of the Houston Section, Rice Institute Branch, and Texas A. & M. College Branch, March 27, 1942.

District 10

Prize for best paper was awarded to D. M. Farnham (M '42) and O. W. Titus (M '36) for their paper, "Design, Manufacture, and Installation of 120-Kv Oil-Filled Cables in Canada," presented at the Pacific Coast convention, Vancouver, B. C., September 9–11, 1942.

Prize for initial paper was awarded to W. R. Way (M '42) for his paper, "Power System Interconnection in Quebec," presented at the Pacific Coast conventions Vancouver, B. C., September 9–11, 1942.

Prize for Branch paper was awarded to H. T. Stevinson (Enrolled Student) for his paper, "Lightning and the Broadcast Transmitter," presented at a meeting of the University of Alberta Branch, Edmonton, March 16, 1942.

Board of Directors Report Omitted From July Issue

Because of governmental limitations on the use of paper the annual report of the AIEE board of directors is not being published in the July issue of *Electrical Engineering* as has been the policy of recent years. However most of the Institute activities reviewed in the report have been reported in *Electrical Engineering* throughout the year.

Members who wish may obtain copies of the 16-page board of directors report from AIEE headquarters, 33 West 39th Street, New York 18, N. Y.

District Numbers Requested for New Addresses

By a recent regulation of the Post Office Department persons living in approximately 175 of the principal cities in the United States have had district numbers added to their addresses. To assist us in meeting the post office ruling, members living in these cities are requested to indicate their Post Office district numbers when informing headquarters of changes of address. Thus for the future the address of AIEE headquarters will read: 33 West 39th Street, New York 18, N. Y.

Additions to List of Members for Life

Membership for life is granted by the AIEE to members who either have paid annual dues for 35 years, or have reached the age of 70 and paid dues for 30 years. A list of those who have become members for life during the preceding year is published annually in *Electrical Engineering*. Institute members who have attained this status since publication of the last list in July 1942, are:

H. G. Acres
E. H. Acton
H. V. Allen
R. J. Andrus
J. C. Armor
F. R. Bacon
B. F. Bailey
C. E. Banta
M. Barnert
J. T. Barron
W. O. Batchelder
C. R. Beardsley
J. D. G. Beaubien
M. Berthold
P. S. Biegler
L. S. Billau
E. H. Billipp
J. E. Boesch
F. Borch
W. S. Bourlier
F. K. Brainard
A. T. Childs
C. V. Christie
M. H. Clapp
C. L. Collens
T. R. Cook
C. P. Cooper
H. H. Cox
L. P. Crecelius
F. B. Crosby
F. Daugherty
C. M. Davis
J. G. De Remer
L. E. Dickinson
W. N. Dickinson
C. R. Dooley
D. C. Durland
C. F. Elwell
W. G. B. Euler
H. W. Evans
L. Evans
F. H. Froehlich
J. R. W. Gardam
H. O. Garman
H. Gebhart
V. E. Goodwin
E. W. Gough
S. H. Grauten
H. G. Hake
A. A. Hall
R. H. Halpenny
I. E. Hanssen
H. C. Hawkins
C. A. Heinze
F. K. T. Hepburn
J. H. Hertner
H. Hertz
A. Hertz
G. A. Hodge
F. D. Hoge
F. H. Hollister
A. J. Horton
H. W. Hough
H. G. Howard
L. S. Ickis
B. G. Jamieson
A. J. Jones
A. L. Jones
F. P. Jones
F. L. Kemp
J. L. Kilpatrick
C. L. Kinsole
H. T. Kohlhaas
W. C. Lane
G. F. Leake
A. W. Lee
E. H. Le Tourneau
H. O. Lewis
L. V. Lewis
J. F. Lincoln
J. J. Linebaugh
W. MacLachlan
C. MacMillan
C. A. Mally
R. H. Manahan
H. L. Martien
J. M. S. Maxwell
W. R. McCann
J. R. McFarlin
E. G. Merrick
G. S. Merrill
J. F. Meyer
G. Mezger
C. B. Mirick
R. F. Monges
G. H. Morse
R. C. Muir
N. J. Neall
L. J. Newman
G. Pace
J. C. Peet
A. S. Peters
J. R. Price
F. H. Pritchard
A. Raynsford
N. Read
W. A. Reece
C. R. Riker
H. Rowe
F. O. Runyon
C. P. Schroeder
I. H. Sclater
N. Shute
J. E. Smith
R. W. Sorensen
W. B. Stelzner
J. C. Stephens
F. Stern
H. R. Summerhayes
A. A. Thompson
A. W. Thompson
P. Thut
R. H. Tillman
J. H. Tracy
M. O. Troy
E. E. Turkington
W. L. Upson
L. B. Vanderbilt
S. S. Watkins
J. W. Watson
L. W. Webb
F. Wenner
A. Westman
J. M. Whalen
W. E. Wickenden
F. W. Willey
L. R. Woodhull
J. L. Woodress
F. B. Wright
W. Wurth
R. M. Wynn
A. V. Youens
C. R. Young
W. A. Young

BRANCH

Vanderbilt University Forms AIEE Branch

An AIEE Student Branch authorized at the January meeting of the AIEE board of directors was organized recently at Vanderbilt University, Nashville, Tenn. This is the 125th Branch to be organized.

Officers who will serve until December 31, 1943 were elected on March 22. The enrolled students elected are:

Chairman—Henry M. Bailey.
Vice-chairman—James E. Atkinson.
Secretary-treasurer—Fred T. Ragan, Jr.

Professor S. R. Schealer (M '23) was elected Branch counselor.

SECTION

Fourth Canadian Section Organized at Montreal

The fourth AIEE Canadian Section and the fifth Section to be formed outside the United States held its organization meeting April 16, 1943, at Montreal, Que. Formation of the new Section had been authorized at the January meeting of the AIEE board of directors.

The following officers were elected to serve until July 31, 1943:

Chairman—Frederick Krug (F '36) general manager, Montreal (Que.) Engineering Company.

Secretary-treasurer—D. M. Farnham (M '42) assistant distribution engineer, Montreal (Que.) Light, Heat and Power Consolidated.

Chairman program committee—J. J. Dougherty (A '30) Eastern Power Devices, Ltd., Montreal, Que.

Executive committee—J. L. Clarke (M '30) transmission engineer, Bell Telephone Company of Canada, Montreal, Que.; F. L. Lawton (M '36) assistant chief engineer, Aluminum Company of Canada, Montreal, Que.; N. L. Morgan (A '17) cable engineer, Northern Electric Company, Ltd., Montreal, Que.; and G. A. Wallace (A '20) assistant professor of electrical engineering, McGill University, Montreal, Que.

At the meeting, District 10 initial paper prize was presented to W. R. Way (M '42) for his paper, "Power-System Interconnection in Quebec," and the District best paper prize to D. M. Farnham and O. W. Titus (M '36) for their paper, "Design, Manufacture, and Installation of 120-Kv Oil-Filled Cables in Canada," both presented at the Pacific Coast convention in September 1942.

ABSTRACTS

TECHNICAL PAPERS previewed in this section were presented at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943, and are expected to be ready for distribution in advance pamphlet form within the current month. Copies may be obtained by mail from the AIEE order department, 33 West 39th Street, New York 18, N. Y., at prices indicated with the abstract; or at five cents less per copy if purchased at AIEE headquarters or at the meeting registration desk.

Mail Orders will be filled
AS PAMPHLETS BECOME AVAILABLE

Air Transportation

43-123—Aircraft Electric-Power-Supply System; *J. E. Yarmack (M '42). 15 cents.* Large aircraft are now being equipped with electrically powered accessories, necessitating an electric plant of far greater size than has been available to date. Indications are that future electric load will be on the increase. One possible way of coping with its growth is to generate alternating current in the same manner as conventional direct current and then either to transformer or to convert, or both, by means of separately installed transformers and rectifiers. The electro-physical laboratory of Chrysler Corporation, under the direction of G. C. Goode and F. J. Finkenauer, Jr., together with the author, have designed and built several a-c–d-c aircraft systems utilizing alternators, Selenium rectifiers, and transformers. This paper contains a brief summary of factors entering into the design and construction of these component units and represents a current report on development and test work now in progress.

43-124—Characteristics and Applications of the General Electric Selenium-Rectifier Cells. *By Edgar A. Harty (M '36). 20 cents.* This paper describes the d-c and a-c characteristics of a new type of selenium-rectifier cell as developed by the General Electric Company. Complete design information is given to enable engineers who are not rectifier specialists to apply these cells to rectifier circuits. Data are shown in tabulated as well as curve form to permit estimating voltages and current input and output values. Single- and three-phase circuits are discussed. Information on life, aging, efficiency, and temperature characteristics is given. Finally an example is worked out using the data contained in this paper.

43-125—Fundamental Principles of Amplidyne Applications; *F. E. Crever (A '27). 15 cents.* The amplidyne generator has been applied widely and is recognized as an important device in the electrical industry. Since it is used primarily as a power amplifier in regulating systems, the requirements of an amplifier for this use are analyzed and the characteristics of the amplidyne generator are compared in this paper with these requirements. Because of the large number of distinct windings of the amplidyne, it is desirable to follow a consistent practice in terminal markings and polarities. Proposals for this purpose are outlined in the paper, and typical values of amplification for different output ratings are given. Service experience and an application typifying the use of the amplidyne are discussed, so that the reader may become familiar with the device and its uses.

43-126—Design Relationships for D-C Generators for Use in Aircraft; *S. R. Bergman (A '04). 15 cents.* The electric power in aircraft is based on a 24-volt system. It consists of d-c generators in conjunction with a 24-volt storage battery. The generators are mounted on the main engines, and in large Navy planes there are, in addition, generators driven by auxiliary engines. Certain requirements in both electrical and mechanical design are imposed by the fact that a plane is flying through varying altitudes, resulting in changing atmospheric conditions, such as rarefication, low temperature, and ionization. Other unusual conditions are created from the motion of the plane setting up accelerating forces on the generator, as well as mechanical forces caused by engine vibrations. Because of important features such as commutation, voltage regulation, cooling, driving means, and light weight, special and unusual methods must be employed. In solving these problems the most perfect methods known in the art of building d-c machines must be resorted to. The paper lays particular stress on the use of compensation.

43-127—Aircraft Inverter Construction; *C. T. Button* (*A '26*). *15 cents.* The paper discusses design requirements of aircraft inverters used for conversion of direct current at 27.5 volts to 400 cycles single- and three-phase alternating current. The 400-cycle output is used for operation of instruments, radio compass, fluorescent lighting, automatic pilots, and so forth. Various basic types of rotary inverters are listed, with relative merits and characteristics given in general terms. The desired features of design and operation are given, of which minimum weight and high efficiency are most important. Different types of control accessories for obtaining required voltage and frequency control and freedom from radio interference are described.

43-128—Aircraft Circuit Breakers; *C. W. Kuhn* (*F '39*). *15 cents.* The electric system of military aircraft contributes largely to their effectiveness. Any part of the electric system may be damaged in battle. Airplane-type circuit breakers keep, as much of the system as possible, available at all times. They must meet the special requirements of aircraft service. Minimum size and weight are of unusual importance. This is obtained by combining circuit protection with switch or contactor. The principle function of both manual- and remote-control circuit breakers is to provide short-circuit protection. There is some question as to the desirability of motor protection for military aircraft. Many motor functions are vital to the operation of the aircraft, and it may be better to operate the motor to destruction rather than to stop at a safe temperature or load value. Where motor overload protection is desired, it is necessary to correlate circuit-breaker and motor characteristics. Both manual- and remote-control circuit breakers can be made to provide for holding the circuit closed in emergency to "force" the motor or other equipment.

43-129—Principles of Aircraft Electric-Motor Protection; *V. G. Vaughan. 15 cents.* This paper discusses the steps to be followed in arriving at the proper kind of inherent overheat protection for aircraft electric motors. There is brought out the great range of ambient temperatures encountered. It stresses the need of protecting at temperatures just short of the destructive temperature. Overprotection should be avoided. It is better to have an occasional burn-out than to limit the output of all motors. Locked rotor protection only should be avoided, for when a motor protector has been applied for locked rotor protection only, then at running loads the motor may be underprotected or overprotected. All available output of the motor with complete protection for all conditions can only be obtained when the protector application is engineered to meet the various ambients and load conditions which may be encountered in aircraft flying in any part of the world.

43-130—Manual Switches for Aircraft; *R. A. Millermaster* (*M '34*). *15 cents.* Manual switches for aircraft are applied in a rapidly expanding and changing field where rapid obsolescence of past practices is the rule. The switch manufacturer cannot keep informed of all utilization equipment changes. Experience has proved it preferable that the manufacturer make available complete performance data on his switches, so that the aircraft manufacturer can himself match the control means to the utilization device. To provide usable performance data, the switch manufacturer must include measures of the switch capacity to establish, maintain, and interrupt a circuit, modifying each rating in terms of the load characteristics—such as inrush values, inductance, voltage, and current. He must also include performance data related to the chemical and physical surroundings in which the switch will function, and these will include ambient temperature, humidity, chemical atmosphere or sprays, accelerations, and air pressure. Tests to determine these are described.

43-131—Aircraft Contactors; *F. J. Russell* (*M '37*) and *A. P. Charbonneau. 15 cents.* Design of contactors for use in aircraft follows principles developed for commercial contactors, but many new problems are encountered. An analysis of the operation of the contacts aids in determining the work curve and the pull required from the magnet. With these factors determined, the design may be made to provide the greatest utilization of material and space, very important consideration on all devices used on aircraft. Circuit requirements demand contactors having a range of ratings up to 200 amperes continuous duty and various combinations of normally open and normally closed contacts. A line of contactors embracing these combinations has been developed embodying the features required for aircraft service.

43-132—Radio-Noise Filters Applied to Aircraft; *C. W. Frick* (*A '19*), *and S. W. Zimmerman* (*M '40*). *20 cents.* Performance characteristics of radio-noise suppression devices including capacitors as well as filters are described. Available filters for use in aircraft are described as to current and voltage ratings, dimensions, weight, suppression ratios, and other features. An elementary case of a power circuit to which suppression is applied and a paralleling radio system are discussed, for the purpose of bringing out some important considerations in the selection, installation, and testing of suppression devices, as well as some of the terms commonly used. Conditions under which each of the two suppression devices, filters and capacitors, may be used effectively are pointed out. Measurements which check the performance of suppressors on actual equipment are described. Measurements are also described which are made on an accepted laboratory circuit for rating purposes and for checking the product of the factory. The laboratory circuit is analyzed in an appendix.

Electrical Machinery

43-109—Interim Report on Overloading Current-Limiting Reactors; *transformer subcommittee of committee on electrical machinery. 15 cents.* The "Interim Report on Guides for Overloading Transformers and Voltage Regulators," which was presented at the AIEE summer convention, June 22 1942, and was published in *AIEE Transactions,* volume 61, 1942, September section, pages 692–4, gave information on the overloading of all types of transformers and of voltage regulators. An additional report, specifically applicable to the operation of distribution transformers, has already been issued and is soon to be published. A third report, covering the related problem of overloading current-limiting reactors, is now being issued for use in conjunction with these two reports. Recommended overloads and maximum operating temperatures are presented for oil-immersed and dry-type reactors installed in the open or enclosed in compartments.

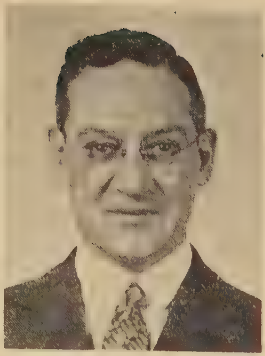
PERSONAL • • • •

P. M. Gee (A '11, M '21) division engineer, Consolidated Edison Company of New York (N. Y.), Inc., has retired. He received his bachelor of science degree from Clemson College in 1909 and then spent one year in the student engineering course of the General Electric Company, Pittsfield, Mass. From 1910 to 1912 he worked in the testing department at Schenectady, N. Y. In 1912 he became assistant chief inspector of assembled switchboards and in 1913 was made switchboard designing engineer. From 1915 to 1917 he worked as designer for Stone and Webster, Boston, Mass. He commenced his 26-year association with the Edison system in 1917 as foreman for the Brooklyn (N. Y.) Edison Company. In 1922 he was made chief electrical draftsman and in 1923 assistant engineer. He was appointed division engineer in 1929 and, as such, was transferred to the Consolidated Edison company's inside plant department in 1936.

C. F. Wagner (A '20, F '40) manager of the central station engineering department Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been awarded the 1942 national best paper prize

C. F. Wagner

T. D. Graybeal



Herman Halperin

G. D. McCann

in theory and research as coauthor of the paper, "Shielding of Substations." He received the degree of bachelor of science from the Carnegie Institute of Technology in 1917. In 1918 he entered the employ of the Westinghouse company as research assistant in the materials and processes engineering department. He was transferred to the porcelain insulators and transmission engineering department in 1924. In that department he was occupied chiefly with stability problems directed toward improving transmission. In 1938 he was appointed consulting transmission engineer and in 1941 manager of the central station engineering department. Previously he was awarded the national best paper prize in engineering practice in 1938, as well as the George Montefiore award in 1929. Numerous patents have been issued to him. He has served on the AIEE committee on power transmission and distribution from 1930 to 1932 and again from 1937 to 1943.

T. D. Graybeal (A '38) instructor in electrical engineering, University of California, Berkeley, has been awarded the 1942 national best paper prize for his initial paper, "Steady-State Theory of the Amplidyne Generator." He was graduated from the University of California in 1937 with the degree of bachelor of science in electrical engineering. In 1939 he received the degree of master of science from Massachusetts Institute of Technology and in 1941 the degree of doctor of engineering from Yale University. From 1937 to 1939 he was research assistant at Massachusetts Institute of Technology, Cambridge. In 1939 he became assistant in instruction at Yale University, New Haven, Conn., and in 1941 was appointed instructor in electrical engineering at the University of California. He is a member of Tau Beta Pi.

Herman Halperin (A '21, M '26) assistant equipment and research engineer, Commonwealth Edison Company, Chicago, Ill., has been awarded the 1942 national best paper prize in engineering practice for his paper "Load Ratings of Cables—II." He was graduated from Cornell University in 1920 with the degree of mechanical engineer. During 1920 and 1921 he supervised electrical construction for the Union Gas and Electric Company, Cincinnati, Ohio. In 1921 he entered the employ of the Commonwealth Edison Company where he worked on miscellaneous problems connected with underground cable systems. In 1927 he became head of the company's technical division. He was named cable research engineer in 1933 and assistant equipment and research engineer in 1937. He has served on the AIEE committee on protective devices (1925–31, 1937–42), power transmission and distribution (1936–43), and research (1936–39).

G. D. McCann (A '38) transmission engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been awarded the 1942 national best paper prize in theory and research as coauthor of the paper, "Shielding of Substations." Mr. McCann received from the University of California the degrees of bachelor of science in 1934, master of science in 1935, and doctor of philosophy in 1939. In 1938 he entered the employ of the Westinghouse company as central station engineer. In 1941 he became transmission engineer. He is a member of Sigma Xi.

R. C. Van Sickle (A '33, M '37) circuit breaker and protective devices engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has received honorable mention in the 1942 national prize award for the best paper in theory and research for his paper, "Transient Recovery Voltages and Circuit-Breaker Performance." He holds the degrees of mechanical engineer (1923) and electrical engineer (1924) from Cornell University and the degree of master of science from the University of Pittsburgh (1928). He has been associated with the Westinghouse company since 1924. After two years in the student course and the supply engineering department, he became circuit-breaker engineer. From 1928 to 1930 he was exchange and liason engineer for the Westinghouse company at the Siemens Schuckert Works, Berlin, Germany.

F. D. Egan (M '34) electrical superintendent, Bethlehem Steel Company, Lackawanna, N. Y., has been granted an indefinite leave of absence. A past president of the Association of Iron and Steel Engineers, he has been superintendent since 1923. **R. W. Graham** (A '18, M '31) formerly assistant superintendent, will succeed Mr. Egan. Mr. Graham, who was an instructor at Cornell University, Ithaca, N. Y., for three years, has been with the Bethlehem company since 1916. **T. O. Zittel** (A '34) formerly student engineer, will become assistant superintendent. He graduated from Rensselaer Polytechnic Institute in 1933 and was employed by the Bethlehem company in 1935.

E. C. Wentz (A '28, M '42) transformer design engineer, Westinghouse Electric and Manufacturing Company, Sharon, Pa., has received honorable mention in the 1942 prize award for the best paper in engineering practice as one of the coauthors of the paper, "Linear Couplers for Bus Protection." He holds the degrees of bachelor of science (1926) and electrical engineer (1939) from the University of Minnesota and that of master of science (1936) from the University of Pittsburgh. He has been employed by the Westinghouse company since 1926 and is a frequent contributor to electrical publications.

D. E. Trucksess (M '40) research engineer, power apparatus development department, Bell Telephone Laboratories, New York, N. Y., has received honorable mention in the 1942 national prize award for the best initial paper for his paper, "Regulated Rectifiers in Telephone Offices." A graduate of Pennsylvania State College, Mr. Trucksess has been engaged in electrical research at Bell laboratories since 1926. He is the author of numerous articles and holds several patents.

W. K. Sonneman (A '38, M '43) design engineer, Westinghouse Electric and Manufacturing Company, Newark, N. J., has received honorable mention in the 1942 national prize award for the best paper in engineering practice as one of the coauthors of the paper, "Linear Couplers for Bus Protection." He was graduated from the University of Texas in 1924 and worked as design engineer for the Westinghouse company until 1929. As switchboard designer he was employed by the Texas Power and Light Company, Dallas, from 1929 to

1932 and by the Texas State Highway Department from 1933 to 1935 as assistant in highway design and construction. He returned to the Westinghouse company in 1936.

E. L. Harder (A '30, M '41) central station engineer, Middle Atlantic district, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has received honorable mention in the 1942 national prize award for best paper in engineering practice as one of the coauthors of the paper, "Linear Couplers for Bus Protection." He holds the degree of electrical engineer from Cornell University (1926) and that of master of science from the University of Pittsburgh (1930). He has been with the Westinghouse company since 1926 as student engineer, design engineer, and finally, central station engineer. Mr. Harder also received honorable mention in the 1939 national prize award.

W. S. Edsall (M '19) formerly assistant manager of the electrical department, Allis-Chalmers, Manufacturing Company, Boston, Mass., has been made manager of a newly combined swtichgear and control division of the company at Milwaukee, Wis. Mr. Edsall became associated with the Allis-Chalmers company in 1931 when the latter purchased Condit Electric Manufacturing Corporation of which he was a director. He then became sales manager for the Condit works and later of the switchgear division of the Allis-Chalmers company.

W. G. Willson (A '41) formerly manager, Phoenix (Ariz.) office, Westinghouse Electric and Manufacturing Company, has been named Los Angeles (Calif.) manager for that company. He entered the employ of the Westinghouse company in 1913 and had been Phoenix manager for 18 years. **H. S. Warren** (A '35) formerly of the central sales department, Los Angeles, Calif., will succeed Mr. Willson as manager of the Phoenix office. Mr. Warren joined the Westinghouse company at Los Angeles in 1922.

E. H. Klemmer (A '42) switchgear engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has received honorable mention in the 1942 national prize award for the best paper in engineering practice as one of the coauthors of the paper, "Linear Couplers for Bus Protection." A 1925 graduate of the Carnegie Institute of Technology, Mr. Klemmer has been switchgear engineer with the Westinghouse company since 1929.

S. T. Fisher (M '43) formerly sales and development engineer, Northern Electric Company, Ltd., Montreal, Que., has been appointed assistant to the president of Rogers Radio Tubes, Ltd., and special products manager of Rogers Majestic, Ltd., Toronto, Ont. He had been associated with the Northern Electric Company since he received his bachelor of science degree from the University of Toronto in 1930.

C. N. Simpson (M '34) formerly general manager of the Gatineau Power Company, Ottawa, Ont., has been elected vice-president of that company. A graduate of the University of Toronto, Mr. Simpson joined the Gatineau company in 1926 as supervisor of the power developments on the Gatineau river. In 1929 he was appointed chief engineer and in 1935 general manager.

N. E. Funk (A '07, F '34) vice-president in charge of engineering, Philadelphia (Pa.) Electric Company, and new AIEE president-elect, recently received the honorary degree of doctor of engineering from Lehigh University. A fuller biography of Doctor Funk appears in *Electrical Engineering*, March 1943, page 127.

W. B. Schaffir (Enrolled Student) undergraduate at the Case School of Applied Science, Cleveland, Ohio, is the recipient of a $25 award for a paper submitted in the engineering undergraduate award and scholarship program of the James F. Lincoln Arc Welding Foundation.

A. S. Gray (A '41) vice-president of the Insulation Manufacturing Corporation, Chicago, Ill., has been appointed to the Built Up Mica Industrial Advisory Committee recently formed by the War Production Board.

H. J. van der Bijl (M '17) chairman of the Electricity Supply Commission, and chancellor of Pretoria University, Johannesburg, Transvaal, South Africa, is one of five scientists recently elected foreign associates of the National Academy of Sciences.

Delevan Haloran (A '32, M '32) formerly assistant engineer, Consolidated Edison Company of New York (N. Y.), Inc., has been commissioned a senior lieutenant in the United States Navy and is stationed at Savannah, Ga.

W. G. Vreeland (A '39) formerly junior engineer, Consolidated Edison Company of New York (N. Y.), Inc., has secured a wartime leave of absence to join E. H. Badger and Sons, Consulting Engineers, New York, N. Y.

W. D. Coolidge (A '10, M '34) vice-president and director of research, General Electric Company, Schenectady, N. Y., has been awarded the Order of Merit of Chile for his "many services to civilization."

J. L. Holton (A '30, M '37) formerly division engineer, New York and Queens Light and Power Company, Flushing, is now at the Eastman Kodak Company, New York, N. Y., on a wartime leave of absence.

L. W. Long (A '37) formerly factory sales engineer, Allis-Chalmers Manufacturing Company, Pittsburgh, Pa., has been appointed sales engineer in charge of mixed apparatus sales.

W. S. Lee, Jr. (A '30) formerly lieutenant commander, United States Navy, has been appointed commander and now heads the 15th Naval Construction Battalion in the South Pacific.

V. F. Headapohl (A'33) formerly engineer, American Telephone and Telegraph Company, New York, N. Y., has been commissioned lieutenant in the United States Naval Reserve.

OBITUARY

John Stone Stone (A '08) inventor and consulting engineer, died May 20, 1943. Born September 26, 1869, at Dover, Va., he studied at the Columbia University School of Mines and at Johns Hopkins University. From 1890 to 1899 he was employed as an experimentalist in the laboratory of the American Bell Telephone Company, Boston, Mass. He continued with that company in the position of general consulting engineer until 1920. During this period he was a special lecturer on electric oscillations and their applications at the Massachusetts Institute of Technology, Cambridge, for six years. He was vice-president and chief engineer of the Stone Telephone and Telegraph Company, Boston, from 1902 to 1908 when he became president. From 1920 to 1935 he was associate engineer at large in the department of development and research, American Telephone and Telegraph Company, San Diego, Calif. The holder of numerous American and foreign patents pertaining to telephony and wireless telegraphy, he frequently contributed to scientific publications. The Edward Longstreth Medal was awarded him for his paper, "The Practical Aspects of the Propagation of High-Frequency Waves Along Wires," by the Franklin Institute in 1913, and the medal of honor of the Institute of Radio Engineers for distinguished service in radio communication in 1923. A fellow of the Institute of Radio Engineers, he served as president during 1914–15. He was also a fellow of the American Academy of Arts and Sciences and the American Association for the Advancement of Science, and a member of the Society of Wireless Telegraph Engineers and the Franklin Institute.

Ernest W. Muller (A '05, M '13) consulting engineer, Kaiser, Muller and Davies, New York, N. Y., died April 8, 1943. He was born in Rome, Ga., March 5, 1875. His first electrical work was wiring installations at which he was engaged from 1892 to 1894. From 1894 to 1897 he did similar work for the contracting firm of Hatzel and Buehler, New York, N. Y. In 1897 he joined the firm of Mailloux and Knox, Consulting Engineers, New York, N. Y., for whom he became designing and supervising engineer. As such, he was active in the electrification of many of the public buildings, stores, hospitals, and educational institutions in New York and near-by cities. From 1919 to 1943 he was a member of the firm of Kaiser, Muller and Davies. There he specialized in the designing and development of feeder and cable distributing systems and power plant installations. In recent months he had worked with the War Production Board in its efforts to conserve copper and other vital war materials used in electrical installations. He was a member of the New York Association of Consulting Engineers, the Society of American Military Engineers, and a past vice-president of the New York Electrical Society.

William Edwin Douglass (M '37) manager, Panhandle division, Monongahela West Penn Public Service Company, Wellsburg, W. Va., died November 11, 1942. Born April 29, 1890, at Elmwood, Ill., he received the bachelor of science degree from Knox College in 1913 and the degree of electrical engineer from the University of Arkansas in 1919. In 1913 he entered the apprentice course of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. From 1914 to 1919 he was engaged in transformer design and in 1919 was transferred to the company's central station section. In 1923 he entered the employ of the Wisconsin Valley Electric Company, Wausau, where he was charged with generation, and transmission and distribution. He joined the Monongahela West Penn Company as manager of its Clarksburg (W. Va.) division in 1925. In 1932 he was made manager of the Panhandle division. He was a member of the Iron and Steel Association, the American Ceramic Engineering Society, and an ex-chairman of the American Red Cross flood disaster committee.

Albert H. Kreul (A '19, M '32) assistant superintendent, electrical maintenance and construction, Portland (Oreg.) General Electric Company, died May 5, 1943. Born June 14, 1884, at Fennimore, Wis., he was graduated from Iowa State College with the degree of bachelor of science in electrical engineering in 1908 and from the Northwestern College of Law in 1918. His death terminated a 33-year association with the General Electric Company which he joined in 1910. Until 1920 he worked in the meter and service department. From 1920 to 1931 he was engineer in the electrical maintenance and installation department. In 1931 he was made assistant superintendent of the electrical maintenance and construction department. Active in Institute affairs, he served as chairman of the Portland Section for 1930–31 and as a member of the Pacific Coast Convention committee in 1938.

Joseph A. Robinson (A '30) sales engineer, National Carbon Company, New York, N. Y., died May 16, 1943. He was born November 26, 1883, at Waupun, Wis. From 1905 to 1907 he was engaged in research on primary batteries. In 1908 he entered the sales department of the Northwestern Storage Battery Company, Milwaukee, Wis. Since 1911 he had been with the National Carbon Company, first in Cleveland, Ohio, and from 1930 to 1936 in the company's Chicago, Ill., office. He returned to the Cleveland office in 1937 and in 1941 was transferred to New York.

Peter Clark Gill (A '24, M '32) superintendent of transmission and distribution, British Columbia Electric Railway Company, Vancouver, died April 25, 1943. He was born February 22, 1888 at Prescott, Ont., and received his bachelor of science degree in electrical engineering from McGill University in 1910. He immediately entered the distribution engineering department of the British Columbia Electric Railway Company and, in 1914, was given charge of maintenance and construction of the distribution system. In 1929 he was made superintendent of distribution and transmission.

Dudley Owen Nash (A '31, M '38) engineer, sales promotion department, General Cable Corporation, New York, N. Y., died November 6, 1942. He was born September 10, 1899, in Poolville, N. Y. During his service in the United States Army from 1917 to 1919 he worked with antiaircraft searchlights. He entered the employ of the Municipal Light and Power Company, Sherburne, N. Y., in 1919 and engaged in central station operation and construction and maintenance work until 1921. From 1922 to 1929 he managed his own contracting and electrical equipment firm. He joined the General Cable Corporation first in 1929 as specialist and sales engineer. After a short time, from 1934 to 1936, with the Bryant Electric Company, Bridgeport, Conn., as assistant consulting engineer, he returned to the General Cable Corporation.

Robert Henry Anthony (A '17) sales engineer, Boston, Mass., died May 1, 1943. He was born November 17, 1877, at East Providence, R. I., and began his engineering career with the New York, New Haven and Hartford Railroad where he was employed from 1895 to 1911 as roadmaster's chief clerk, engineer, and track supervisor. From 1911 to 1915 he worked as salesman for James C. Barr Company, Boston, Mass. In 1915 he joined R. Thomas and Sons as New England sales representative, and in 1921 he became New England sales manager for the company. Since 1935 he had operated in Boston his own firm which acted as manufacturers representative for numerous companies including the Electroline Company, the G. and W. Electric Speciality Company, the Memco Engineering and Manufacturing Company, the Merit Glove Company, the Minerallac Electric Company, the Naugle Pole and Tie Company, the Pennsylvania Transformer Company, Schweitzer and Conrad, Inc., and the R. Thomas and Sons Company.

David Douglas Murphree (A '40) distribution engineer, Southwestern Gas and Electric Company, Shreveport, La., died May 4, 1943. He was born at Thomaston, Tex., November 14, 1899, and received the bachelor of science degree from the Texas Agricultural and Mechanical College in 1921. From 1927 to 1929 he was distribution engineer with the Galveston (Tex.) Electric Company. He held the same position with the Central Power and Light Company, San Antonio, Tex., from 1929 to 1932. In 1933 he was employed in the commercial department of the San Antonio (Tex.) Public Service Company and in 1936 became distribution engineer with the Southwestern Gas and Electric Company.

Ralph Harold Chadwick (A '17, M '26) assistant to the manager in charge of engineering, General Electric Company, Fort Wayne, Ind., died May 29, 1943. Born at Gardiner, Maine, February 6, 1892, he was graduated from Brown University with the degree of bachelor of science in electrical engineering in 1912. He was enrolled in the General Electric Company test course at Fort Wayne for six months and entered the transformer engineering department in January 1913. In 1926 he was made engineer of the transformer department and in 1941 he was appointed assistant to the manager in charge of engineering. He had served as president of the Fort Wayne engineers club.

Jeth Wesley Dodson (A'38) major, Signal Corps, United States Army, died May 12, 1943. Born in Bryan County, Okla., May 15, 1909, he received the degree of bachelor of science in engineering from the Texas Agricultural and Mechanical College in 1936. From 1936 to 1942 he worked as meterman for the Oklahoma Gas and Electric Company, Ada. He entered the Army in 1942 as a first lieutenant.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners, at its meeting on June 17, 1943, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Attwood, S. S., prof. of elec. engg., Univ. of Michigan, Ann Arbor, Mich.
Bailey, E. L., elec. engr., Chrysler Corp., Detroit, Mich.
Camilli, G., research & development engr., General Elec. Co., Pittsfield, Mass.
Hartley, P. H., chief engr., Philadelphia Elec. Co., Philadelphia, Pa.
Ross, R. H., division plant supt., American Tel. & Tel. Co., Philadelphia, Pa.
Seelye, H. P., senior engr., Detroit Edison Co., Detroit, Mich.

To Grade of Member

Adams, J. A., senior engr., Philadelphia Elec. Co., Philadelphia, Pa.
Angevine, O. L., engr., Stromberg-Carlson Co., Rochester, N. Y.
Bedford, B. D., elec. engr., General Elec. Co., Schenectady, N. Y.
Beeman, D. L., engr., General Elec. Co., Schenectady, N. Y.
Bond, E., elec. engr., Union Carbide Co., Niagara Falls, N. Y.

Broschart, C. B., application engr., Bradley Co., Philadelphia, Pa.
Brown, P. F., plant engr., Indiana Bell Tel. Co., Indianapolis, Ind.
Caldwell, B. H., designing engr., General Elec. Co., Schenectady, N. Y.
Charlesworth, G., elec. engr., Iowa State Commerce Commission, Des Moines, Iowa.
Dunnewold, L. J., toll plant engr., Indiana Bell Tel. Co., Indianapolis, Ind.
Ericson, R. C., engr., Northern Indiana Pub. Serv. Co., Hammond, Ind.
Falck, K. J. C., senior engr., Philadelphia Elec. Co., Philadelphia, Pa.
Fehr, R. O., engr., General Elec. Co., Schenectady, N. Y.
Frey, H. A., research and development engr., Locke Insulator Corp., Baltimore, Md.
Halberg, M. N., member of Industrial Engg. Dept., General Elec. Co., Schenectady, N. Y.
Johnson, T. C., elec. engr., General Elec. Co., Schenectady, N. Y.
Jones, B. W., consulting engr., General Elec. Co., Schenectady, N. Y.
Kennedy, A., engr., General Elec. Co., Schenectady, N. Y.
Kuehni, H. P., elec. engr., General Elec. Co., Schenectady, N. Y.
Lauder, A. H., elec. engr., General Elec. Co., Schenectady, N. Y.
LeVesconte L. B., district engr., Westinghouse E. & M. Co., Chicago, Ill.
Levoy, L. G., elec. engr., General Elec. Co., Schenectady, N. Y.
Lockie, A. M., development engr., Westinghouse E. & M. Co., Sharon, Pa.
Merrick, E. G., elec. engr., General Elec. Co., Schenectady, N. Y.
Pendleton, W. W., research engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Peters, R. H., district engr., Southwestern Bell Tel. Co., Houston, Texas.
Pope, R., member of technical staff, Bell Tel. Labs., Inc., New York.
Robinson, P. W., section head, General Elec. Co., Schenectady, N. Y.
Schroeder, E. H., div. supt. of installation, Western Elec. Co., Philadelphia, Pa.
Stack, G. E., control engr., General Elec. Co., Schenectady, N. Y.
Sweet, A. L., section head, General Elec. Co., Schenectady, N. Y.
Walker, W. G., senior engr., Philadelphia Elec. Co., Philadelphia, Pa.
Ward, S., draftsman and supervisor, Ward Leonard Elec. Co., Mt. Vernon, N. Y.
Westendorp, W. F., research engr., General Elec. Co., Schenectady, N. Y.
Wetmore, W. F., elec. engr., Detroit Edison Co., Detroit, Mich.
Wilson, A., mgr., transmission and distribution dept., Philadelphia Elec. Co., Philadelphia, Pa.

36 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical District. Any member objecting to the election of any of these candidates should so inform the national secretary before July 31, 1943, or September 30, 1943, if the applicant resides outside of the United States or Canada.

To Grade of Fellow

Becker, J. A., Bell Tel. Co., New York, N. Y.
Sheldon, H. H., 80 West 40th St., New York, N. Y.

To Grade of Member

Ahmed, A. A. (Re-election), Ein-Shems, Nr. Cairo, Egypt.
Bjorquist, C. H., Bonneville Pr. Adm., Portland, Oreg.
Bowman, K. K., Gen. Elec. Co., Schenectady, N. Y.
Braunwarth, W. W. (Re-election), Amer. Tel. & Tel. Co., Phila., Pa.
Brooke, G. M. (Re-election), U. S. Maritime Comm., Oakland, Cal.
Desloover, J. R., Quebec Pub. Serv. Board, Montreal, Canada.
George, B. J. (Re-election), Kansas Pr. & Lt. Co., Kansas City, Mo.
Hieronymus, T. G. (Re-election), Kansas City Pr. & Lt. Co., Kansas City, Mo.
Mintz, N. M., N. M. Mintz & Associates, Chicago, Ill.
Parrish, E. W., Florida Pr. Corp., St. Petersburg, Fla.
Pearce, W. J., Mutual Boiler Ins. Co., Boston, Mass.
Quinn, R. F., Gen. Elec. Co., Schenectady, N. Y.
Rollo, W. S., British Army Staff, Washington, D. C.
Sheffield, H. M., Douglas Aircraft Co., Long Beach, Cal.
Swank, A. J. (Re-election), Pacific G. & E. Co., San Francisco, Cal.

15 to grade of Member

To Grade of Associate

United States and Canada

1. North Eastern

Anderson, A. F., Boston Edison Co., Boston, Mass.
Anderson, H. C., Jr., Gen. Elec. Co., Schenectady, N. Y.
Berry, T. M. (Re-election), Gen. Elec. Co., Schenectady, N. Y.
Bloomquist, W. C., Gen. Elec. Co., Schenectady, N. Y.
Broch, F. J., Stone and Webster, Boston, Mass.
Hamilton, L. L., Gen. Elec. Co., Boston, Mass.
Swarthout, R. W., Gen. Elec. Co., Schenectady, N. Y.

2. Middle Eastern

Bennon, M., Philadelphia Navy Yard, Philadelphia, Pa.
Bowen, C. M., Consolidated Gas El. Lt. & Pr. Co., Baltimore, Md.
Brewer, N. R., Arthur G. McKee Co., Cleveland, Ohio.
Douglas, A., Cleveland Elec. Ill. Co., Cleveland, Ohio.
Ellerbe, E. B. (Re-election), W. E. & M. Co., Charleston, W. Va.
Eppley, I. C., Dayton Pr. & Lt. Co., Dayton 2, Ohio.
Fox, J. J., W. E. & Mfg. Co., Erie, Pa.
Gallagher, E. I., Phila. Elec. Co., Philadelphia, Pa.
Gibbs, J. C., Cons. G. E. & Pr. Co., Baltimore, Md.
Harding, R. L., Susquehanna Elec. Co., Conowingo, Md.
Klotz, J. W., Phila. Navy Yard, Phila., Pa.
Kyser, R. H., Naval Research Lab., Washington, D. C.
McCleery, H. D., Fairbanks Morse & Co., Cleveland, Ohio.
Miller, W. S., I-T-E Circuit Breaker Co., Phila., Pa.
Monroe, W. L., W. E. & M. Co., Sharon, Pa.
Picking, J. W., Reliance Elec. & Engg. Co., Cleveland, O.
Plummer, C. B., Federal Communications Com., Washington, D. C.
Spikes, C. W., Sr., Steel Improvement & Forge Co., Cleveland, O.
Stritehoff, D. A., Cons. G. E. & Pr. Co., Baltimore, Md.
Walch, K. R., Gen. Elec. Co., Philadelphia, Pa.
Yanda, G. J., Cleveland Elec. Ill. Co., Cleveland, Ohio.

3. New York City

Barnard, K. H., Pacific Mills, New York, N. Y.
Brechbuhl, L. M., Fed. Tel. & Radio Corp., Newark, N. J.
Broughton, L. I. (Re-election), Bell Tel. Co., New York, N. Y.
Feinsilver, A. S., Crocker-Wheeler Mfg. Co., Ampere, N. J.
Goddard, R. C., Nat. Union Radio Corp., Newark, N. J.
Harris, R. W., Kerite Cable Co., New York, N. Y.
Johnson, H., Sperry Gyroscope Co., Inc., New York, N. Y.
Jordan, W., III, Newark College of Engg., Newark, N. J.
Lang, H. S., Curtis Wright Corp., Caldwell, N. J.
Lewson, M., Camp Evans Signal Lab., Belmar, N. J.
Plascjak, A. M., U. S. Navy, New York, N. Y.
Sattler, R. T., 150 Pacific Ave., Jersey City, N. J.
Wang, P. Y., Nat. Resources Comm. of China, New York, N. Y.
Wilentz, E. S., Cox & Stevens, New York, N. Y.

4. Southern

Haley, J. L., Jr., Memphis L. G. & W. Div., Memphis, Tenn.
Mallory, F. D., Jr. (Re-election), Florida Lt. & Pr. Co., Sarasota, Fla.

5. Great Lakes

Ax, L. S., Tri-State College, Angola, Ind.
Ewy, A., Allis Chalmers Mfg. Co., West Allis, Wis.
Gay, M. F., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Green, F. A., W. E. & M. Co., Indianapolis, Ind.
Kemp, H. L., Pub. Ltg. Commission, Detroit, Mich.
Link, E. A., Line Material Co., So. Milwaukee, Wis.
Rockhill, A. H., Bendix Prod. Corp., South Bend, Ind.
Scott, N., General Motors Co., Detroit, Mich.
Strelzoff, J. A., Michigan State College, E. Lansing, Mich.

6. North Central

Bowen, L. R., Pub. Serv. Co. of Colorado, Denver, Col.
Burgess, M. L., W. E. & M. Co., Omaha, Nebraska.

7. South West

Mark, P. W., Kansas G. & E. Co., Wichita, Kans.
McCarthy, W. C., Jr., Kansas City Pr. & Lt. Co., Kansas City, Mo.
Turrell, H. M., Kansas City Pr. & Lt. Co., Kansas City, Mo.
Wentz, R. L., Kansas Gas & Elec. Co., Wichita, Kansas.

8. Pacific

Brand, S., Douglas Aircraft Co., Santa Monica, Cal.
Burch, R. O., Butcher Elec. Co., San Jose, Cal.
Garman, L. G., Mare Island Navy Yard, San Francisco, Cal.
Johnston, J. T., Gen. Elec. Co., Los Angeles, Cal.
Jung, H. E., Southern Cal. Edison Co., Los Angeles, Cal.
Kirsch, W. R., Bethlehem Steel Co., San Francisco, Cal.
Koehne, K. H., Mare Island Navy Yard, San Francisco, Cal.
Moore, E. J., Cons. Vultee Aircraft Corp., San Diego, Cal.
Perrin, W. G., Glendale Pub. Serv. Dept., Glendale, Cal.
Prise, W. J., Moore Dry Dock Co., Oakland, Cal.
Reinhard, J. W., Bur. of Pr. & Lt., Los Angeles, Cal.
Thompson, O. G., Gen. Elec. Supply Corp., San Diego, Cal.

9. North West

Allen, J. W., Boeing Aircraft Co., Seattle, Wash.
Barnes, F. P. (Re-election) Gen. Elec. Co., Seattle, Wash.
Gilbert, R. M., W. E. & M. Co., Seattle, Wash.
Gue, W. M., W. E. & M. Co., Seattle, Wash.
Lantz, M. J., Bonneville Pr. Administration, Portland, Oreg.
Jordan, W. G., Jr., Gen. Elec. Co., Seattle, Wash.
Murphy, H. A. (Re-election), Montana Pr. Co., Philipsburg, Mont.
Parker, F. D. (Re-election), Bonneville Pr. Adm., Vancouver, Wash.
Pattison, J. R., A. S. Schulman Elec. Co., Provo, Utah.
Renz, R. E., W. E. & M. Co., Butte, Mont.

10. Canada

File, S. E., Powerlite Devices, Ltd., Montreal, Quebec, Canada.
Jorgensen, R., Shawinigan Water & Power Co., Montreal, Quebec, Can.
Kelsey, E. S., Northern Elec. Co., Montreal, Quebec, Canada.
Mitchell, D., Toronto Shipbldg. Co., New Brunswick, Canada.
Sutton, A. J., Montreal Lt. Heat & Power Cons., Montreal, Quebec, Can.

Elsewhere

Anscome, L. D., British Thomson Houston Co., Rugby, England.
Ball, C. E., H. M. Naval Base, Portland, Dorset, England.
Clipperton, J. E., Trinidad Leaseholds Ltd., Trinidad, B. W. I.
Hendry, N., Rotax Ltd., London, England.
Higgs, V. A., Ministry of Aircraft Prod., London, England.
Johnston, B. H., North Canterbury Hospital Board, Christchurch, N. Z.
Moguel, H. E., Mexican Light & Power Co., Mexico, D. F.
Velez, J. F., Fed. Communications Comm., San Juan, Puerto Rico.

Total to grade of Associate
United States and Canada, 86
Elsewhere, 8

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York 18, N. Y.

Aloc, Abbas H., 294 S. Wilson Ave., Pasadena, Calif.
Balsley, R. C., 2535 Van Vranken Ave., Schenectady, N. Y.
Bartelink, E. H. B., 1386 Keyes Ave., Schenectady, N. Y.
Bershad, Laurence P., 320 E. Chester St., Long Beach, L. I., N. Y.
Bolljahn, John T., 1436 T St., S. E., Washington, D. C.
Bourque, Hugh O., 1396 Peachtree St., Atlanta, Ga.
Campbell, Dudley E., 834 E. Olive St., Los Angeles, Calif.
Cross, Charlie, 6544—18th Ave., N. E., Seattle, Wash.
Greene, Ensign Daniel E., Jr., 17 School St., Hanover, N. H.
Heckel, Richard D., 426 S. Sycamore St., Wilmington, Del.
Howell, Walter D., Naval Training School, Dartmouth College, Hanover, N. H.
Johnson, James Steven, 1002—8th St., Lake Charles, La.
Jump, James E., 1004 Union St., Schenectady, N. Y.
Lowy, Walter Marion, 6509 Cleveland Ave., Baltimore, Md.
Mushrush, Roy S., Jr., 335 South St., Pittsfield, Mass.
Nelms, William L., Jr., Box 723, Orangeburg, S. C.
Ortner, Max, Jr., 1831 N. Dayton St., Chicago, Ill.
Pecha, Anton F., 22–66—35th St., Astoria, L. I., N. Y.
Pinckert, Walter F., 203 Elmhurst St., San Antonio, Texas.
Sherman, Leslie S., 1186 Wendell Ave., Schenectady, N. Y.
Sulzer, John Henry, Columbia Ave., Union Beach, N. J.
Waychus, Felix John, Austin Hall, Harvard University, Cambridge, Mass.
Webster, J. D., Jr., Temperance Hall, R.D. 2 Schenectady, N. Y.

23 Addresses Wanted

OF CURRENT INTEREST

Inter-American Commission Plans Postwar Development

The United States and the republics of Latin America will continue to co-operate with private enterprise, through an inter-American commission, to further the economic development of the Western Hemisphere, William F. Machold, executive director of the United States Commission of Inter-American Development, stated in a recent issue of *Foreign Commerce Weekly*.

As a result of the Panama Conference of 1939, the governments in each of the 21 Latin-American republics took action in forming and recognizing a system of national commissions, each comprised of five to seven members. With the formation in 1943 of the United States Commission for Inter-American Development, under the chairmanship of Eric A. Johnston, the chain of national commissions was completed. Co-ordinating council for the system is the Inter-American Development Commission, of which Nelson A. Rockefeller is chairman.

Brief though the span of the system's existence is, it has already put into effect those of its aims which need not be postponed for the duration of the war, declared Mr. Machold. Such objectives are: advisory assistance to private enterprise, particularly on a mixed United States and Latin-American capital basis; field studies, such as the United States vegetable oil mission to Brazil, the survey of Caribbean fisheries, and the study of Peruvian manual industries; provision of technical assistance, such as the delegation of mining engineers to Brazil and Peru, and of industrial engineers to Mexico, and the creation of a technical division within the Washington, D. C., office of the parent commission; and the preparation and dissemination of studies interpreting wartime United States government and business activities affecting the Latin-American trade and industry.

Long before Pearl Harbor, however, and before the formal organization of our own commission, the United States contributed to the Good Neighbor policy through stabilization loans, export–import bank credits for needed capital goods which were delivered, and the carrying out of a program to purchase from the Latin-American republics commodities we had formerly bought elsewhere, as well as the increased amount of raw materials needed for our expanding defense effort. Since Pearl Harbor, our government has concentrated on developing maximum production of vital war materials, including copper, tin, tungsten, rubber, quinine, and fibers. Closely allied with these activities are health and sanitation, food production, development of highway, railroad, and air transportation, and rehabilitation operations.

The contributions of our allies in the Western Hemisphere already are a substantial weight in the scales of world struggle, and as members of the United Nations they will share in the conversion of war production to peacetime uses and outlets. The war has not wholly precluded the development or expansion of consumer-goods production and light industries such as textile mills, cement plants, and rolling mills. Construction of the widely known Brazilian steel mill continues. But for the most part, Latin-American development projects must be deferred for the duration, since the exigencies of war point to less shipping space and less machinery and materials.

In the postwar period, the participation of private enterprise in the United States as a partner in hemispheric industrial expansion will be of material assistance in meeting local capital and technological needs. We have the capital, technical skill, and managerial knowledge. Latin America has natural resources and manpower. A mingling of these elements will further the economic development of the other Americas and will increase their per capita purchasing power and capacity to absorb goods. Among many subjects, knowledge must be obtained concerning laws and taxes, the nature and demands of markets, availability of labor, raw materials, and transportation, climatic conditions, and business customs. Then, with the cessation of hostilities, the Americas can widen their scope of activities and undertake the long-range objectives for which sound preparation is being made now.

Army–Navy Use of Radar Described by OWI

The silence which has hitherto surrounded radar, the United Nations' secret weapon that has been employed so effectively in World War II, has been partially lifted at last by an Army–Navy release through the Office of War Information.

A radio detection and ranging device which utilizes the reflecting characteristic of radio waves to determine the direction, distance, and elevation of an enemy object, radar equipment provides the data necessary to aim a gun accurately on a distant enemy airplane or ship beyond the visibility range of the most powerful telescope. It is used by static ground defenses to direct antiaircraft fire on hostile airplanes through a cloud cover and is installed on airplanes and warships as a means of locating and intercepting the enemy in the dark.

Two fundamental discoveries opened the electronic spectrum to radar equipment. On the basis of electronic theory, it was demonstrable that radio waves are reflected as well as absorbed or filtered through solid substances. However, until a few years ago, no one had succeeded in detecting the reflected impulses. Recent research has led to the development of receiving instruments which can pick up and record these waves.

A second discovery has been the creation of instruments which count time intervals smaller than a split thousandth of a second. Although work in this direction has been going forward for years, it was recent experiment that resulted in such high precision as to open the way to radar.

Its advantage over the telescopes and acoustic detectors previously used is one of speed. Sound, picked up by an acoustic detector, travels at approximately 700 miles an hour, or only about twice the speed of a fast bomber. But radio waves, which operate over a much greater distance, carry the warning of approaching airplanes with the speed of light—186,000 miles per second.

As a result of experiment by prominent British and American scientists in the ultra-high-frequency field, radar equipment was devised in both countries in the middle '30's. The British, who call their system the radiolocator, made the first practical use of radar when they withstood the Nazi bombers in the summer of 1940. The American development was done by Army Signal Corps, Navy, and civilian laboratories. American production placed proved field radar apparatus in the hands of the armed forces several months before the Japanese attack on Pearl Harbor, and it was these instruments which detected and located approaching airplanes some 30 minutes before the attack was launched.

Scientifically, radar has the same geneology as the familiar radio. The British physicist, William Clerk Maxwell, in 1864, demonstrated mathematically that light and electricity move in the same medium, and that electricity and light share many of the same characteristics. In 1887, Heinrich Hertz succeeded in producing electromagnetic waves which, as Maxwell had predicted, could be detected at some distance from the originating spark. In the 1890's, Guglielmo Marconi was experimenting with equipment designed to send out longer stronger waves, on the one hand, and on the other hand, to pick up waves at greater distances. He used an aerial and ground on both his sending and receiving apparatus.

The next important step was the use of pioneer vacuum tubes in 1906 by Doctor Lee DeForest. In 1915, Doctor Irving Langmuir designed a tube similar to those used today. The microphone, which translates our speech into radio waves, and the receiver which translates these waves into the radio programs to which we listen, while vital to the development of radio, are not essential to radar.

TVA Completes 13 Dams in Ten-Year Existence

After ten years of operation the Tennessee Valley Authority can point to an achievement record showing 13 large dams constructed, 385 miles of nine-foot navigable channel cleared for year-round transportation, nearly 30,000,000 kilowatt-hours of electric energy generated, 150,000,000 seedling trees planted, and 500,000 tons of phosphate and fertilizer processed, according to a recent review published in *Engineering News Record*.

Eight of the 13 dams into which have gone 7,600,000 cubic yards of concrete and 20-000,000 cubic yards of earth and rock have been constructed under wartime stringencies since 1940. The installed power capacity of its projects has increased from 1,000,000 kw to 1,500,000 kw since Pearl Harbor was attacked. TVA plants have also felt the war stimulus. They are among the largest producers of phosphorous products for incendiary bombs, smoke screens, and tracer bullets. Ammonia and ammonium nitrate for munitions and calcium carbide for synthetic rubber are manufactured by the plants.

About 75 per cent of the installed power capacity of the hydroelectric and steam plants built and purchased by the TVA is contributing to war production. These plants have a power capacity of 1,635,640 kw to which installations now in progress will add 453,200 kw. Nearly 6,000 miles of transmission lines are now in service. Thus the TVA system now ranks second among the power systems of the United States.

Other permanent improvements have resulted from TVA activity in checking soil erosion and in aiding the agricultural economy of the region by developing many small machines for food and feed processing designed primarily for the small, low-income farm unit predominant in the region. Pilot plants for extracting native kaolins for chinaware, alumina from clay, and magnesium from olivene rock have been set up.

On the Tennessee and its tributary rivers, flood storage of 8,000,000 acre-feet in the reservoirs has helped reduce flood crests in the Tennessee, Ohio, and lower Mississippi rivers. Navigation has increased from 32,660,000 ton-miles in 1933 to 161,470,000 ton-miles in 1942 as TVA control kept a more uniform supply of water in the river bottoms.

For the future TVA has scheduled the completion of the Fort Loudon and Kentucky dams and dredging operations required to extend the 9-foot navigation channel from the mouth of the Tennessee river to Knoxville, Tenn. River freight terminals are also under construction.

The impact of the program on the four states in the valley, Tennessee, Alabama, Georgia, and Mississippi, may be indicated by figures recently released by TVA Director J. P. Pope. According to these estimates economic progress in the area for the past decade has exceeded the average for the country. Manufacturing plants in the four states increased production 52 per cent from 1933 to 1939 compared with 32 per cent for the nation. Wage earnings increased 40 per cent compared with 36 per cent elsewhere. Per capita income rose 75 per cent compared with 56 per cent for the whole country.

Shortage of Engineers Threatens War Industry

Between 40,000 and 50,000 engineers are vitally needed in war industry to raise production to capacity or to start new productive units operating before the end of 1943, according to a report made to Paul V. McNutt, chairman of the War Manpower Commission, by the National Roster of Scientific and Specialized Personnel.

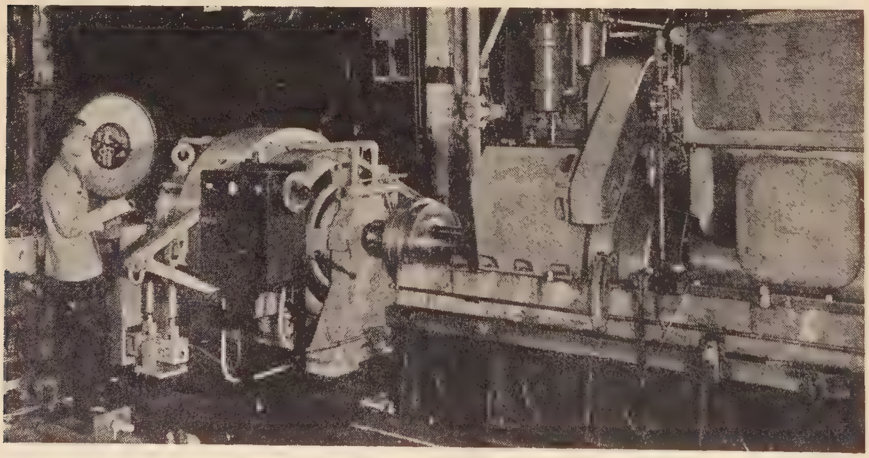
With the graduating classes of the country's engineering schools supplying only about 17,000 new engineers, of whom 6,000 are committed to the armed services, there must be a reapportioning of those already employed. The report points out that the plants which have reached the stage of routine production are in a better position to stand the loss of technically trained men than the expanding war industries.

In appraising the numbers that might be made available for war production in this manner, the report estimates that, of 280,000 American engineers, 19 per cent are in the armed forces or in civilian jobs in the War and Navy Departments; 12 per cent are in other governmental positions; 49 per cent are employed in manufacturing, mining, and construction; and 20 per cent are employed in transportation, communication, public utilities, private consulting offices, and educational institutions. The fields of electrical, radio, mechanical, aeronautical, marine, and industrial engineering are those in which the scarcity is most apparent.

In addition the report suggests that the 1943 engineering graduates who are not needed by the armed forces to fill specific technical posts may be of greater aid in the war effort if they are released to war industry.

Some relief for the situation may be expected from the more profitable employment of nonengineering personnel. Skilled workers must be occupied at their highest skills, while less technical operations can be left to men and women with more limited training. The simpler engineering tasks may be turned over to technical assistants. The engineering, science, and management war training college courses sponsored by the government and now open to high school graduates will provide such assistants.

Marine Diesels Put Under Working Strains



This General Electric water-cooled inductor dynamometer is pictured as it is employed at the Enterprise Engine and Foundry Company, San Francisco, Calif., in giving a ten-day test under simulated operating conditions to a 1,000-horsepower eight-cylinder Diesel engine used in many types of seacraft. The dynamometer can absorb 3,500 horsepower over a range of 850 to 2,500 rpm.

Electronic Checkup Given to Army's Powder

The modern United States Army not only keeps its powder dry but examines powder production runs for variations in ballistic factors that might cause errors in fire-control calculations. This makes possible greater precision in setting up intricate ballistic formulas.

The powder is tested by exploding a sample in a strong sealed container. Electric voltages from the confined detonation reach the horizontal and vertical plate pairs of a cathode-ray tube through suitable amplifiers. The resulting oscillogram is photographically recorded and later analyzed. The screen calibrates the qualitative story of the graph by applying a series of dots arranged in a matrix. Each luminous dot is electronically placed on the screen so that the horizontal or vertical distance between any two adjacent dots is a constant known factor.

The operator of the oscillograph actuates a plunger which automatically opens the camera shutter, turns on the cathode-ray beam, fires the powder charge, switches the input of the deflection amplifiers from bomb chamber to matrix generator, causes the "equipotential" matrix to appear, turns off the electron beam, and then closes the camera shutter. The machine used to perform this series of operations was designed and built by the Allen B. Dumont Laboratories, Inc., Passaic, N. J.

Sea-Rescue Lamp Designed for Life Rafts

A midget searchlight built into a bulb no larger than a walnut has been developed by the lamp division of Westinghouse Electric and Manufacturing Company, Bloomfield, N. J., to aid the rescue of aviators forced down at sea.

Designed at the request of the United States Navy, the lamps will be packed with the rubber life rafts with which all ocean-flying military aircraft are now equipped. Each man of a plane crew forced down at sea will wear one of them fitted on a band around the head, like a miner's cap, so that both hands can be free to hold on in rough weather.

One half of the six-watt bulb is silvered to provide its own reflector and to prevent diffusion of the beam. The lamps will be wired to a small hand-cranked generator which is included in the raft equipment to supply power for the radio. They can also be flashed as signal lamps by means of a "trigger switch."

Theoretically, the tiny incandescent unit will project a 1,500-candlepower beam visible for 60 nautical miles, but in practice, water vapor in the air reduces the visibility range of the beam somewhat. If burned all night long, it is estimated that one of the lamps would last about ten nights or 100 hours.

Bituminous Coal Users Urged to Order Now

A government program to spread the mining and delivery of bituminous coal more uniformly over the summer and thus prevent a heavy seasonal strain on production and transportation next winter has been announced by Solid Fuels Administrator Harold L. Ickes.

Stating that the adequacy of next winter's coal supply depends on the success of the program, Mr. Ickes placed responsibility for this success with the consumer whose orders must set it in motion.

"A bituminous coal user's best wartime fuel insurance is to place his order now; allow his dealer or supplier the greatest possible latitude as to kind, quality, and size; co-operate with his dealer on delivery arrangements, and store the coal as it can be made available," according to Mr. Ickes.

He urged consumers to accept any usable coal their dealers recommend rather than risk being left without fuel. In stressing the importance of ordering the coal now, he said that "in view of the uncertainties about conditions which might arise next winter in the regions where bituminous coal is now being produced, we cannot afford to lose the production and distribution of a single ton that can be moved this summer."

A program to insure an adequate supply of anthracite coal is also being formulated according to the administrator.

WPB Reports Progress of Copper Recovery

Some 197,000,000 pounds of idle and excessive copper scrap has so far been turned into war-production channels, according to a recent announcement of the War Production Board. Of this amount, 62,000,000 pounds is in the form of fabricated copper and copper-base alloy. The regular scrap market has absorbed 30,000,000 pounds while 93,000,000 pounds has been allocated for remelting. Users were found for 56,000,000 pounds in the form in which it was reported. The remaining 17,000,000 pounds has been retained by owners for production.

The foregoing amounts represent two thirds of the amount of copper scrap reported to the WPB in response to its efforts to locate the 400,000,000 to 500,000,000 pounds of scrap which experts estimated to be extant. So far 114,000 firms have been approached and plans are under way to reach 98,000 plumbers, building contractors, and their suppliers.

Of the remaining 100,000 pounds reported, approximately 36,000,000 pounds consists of assembled products contaminated with materials not suitable for copper scrap. Arrangements for removal of the remainder by the Copper Recovery Corporation are still in progress.

Brazilians in United States Study Powder Metallurgy

New applications of the science of powder metallurgy as used in the United States to speed war production will be carried back to Brazil by two scientists now studying here. They are Doctor Tharcisio D. deSouza Santos and Vincente Chiaverini, engineers from the Institute of Technological Research in Sao Paulo, now investigating metallurgical processes in the metal-powder laboratory of Stevens Institute of Technology, Hoboken, N. J.

After an intensive three-month course and a month spent in visiting American plants and factories, they will return to Brazil to set up a metallurgical laboratory there. As yet, there is none in any educational institution in Brazil, they said. Doctor Santos plans to center his study on the operation of the high-frequency melting furnace, the production of carbide cutting tools, ore reduction, and the application of powder metallurgy. Mr. Chiaverini will specialize in hard metallic carbides and the operation of equipment used in their processing.

Latin Americans Study Rural Electrification in U. S.

Eighteen engineers from 14 Latin-American countries, who are in the United States studying rural electrification, recently completed a 3,900-mile tour of north, central, and eastern industrial centers. The trip enabled the men to observe the production of a full line of equipment for the construction and operation of rural power lines, generating plants, electrical labor-saving farm equipment, and other devices which will be needed for postwar rural electrification in their own countries.

The tour, arranged by the Rural Electrification Administration, in co-operation with the Office of Co-ordinator of Inter-American Affairs and the Office of Foreign Agricultural Relations in the Department of Agriculture, took the group to 15 industrial cities in eight states. Before their return home to start developing their own rural electrification programs they will visit REA-financed electric distribution systems under actual operating conditions.

This is the second year the REA has arranged for a delegation of Latin-American student-engineers to study the rural electrification program in this country.

Pacific Northwest Area Receives Power From Shasta Turbines

Two 75,000-kw turbine generating units, originally constructed for Shasta Dam of the Central Valley project in California, have been rushed into place at Grand Coulee Dam by the Bureau of Reclamation to meet additional load requirements in that area.

The Shasta units were completed in advance of the Shasta power plant, and the transfer was made in order to provide extra power for war industries in the Pacific Northwest. Other units will be available for Shasta by the time it is able to generate power. Because the turbines for the two projects were not of the same design, a number of adaptations were required in effecting the change.

The turbines operate at a capacity load of 103,000 horsepower at 330-foot head. It is expected that two more 108,000-kw generators also will be installed this year at Grand Coulee.

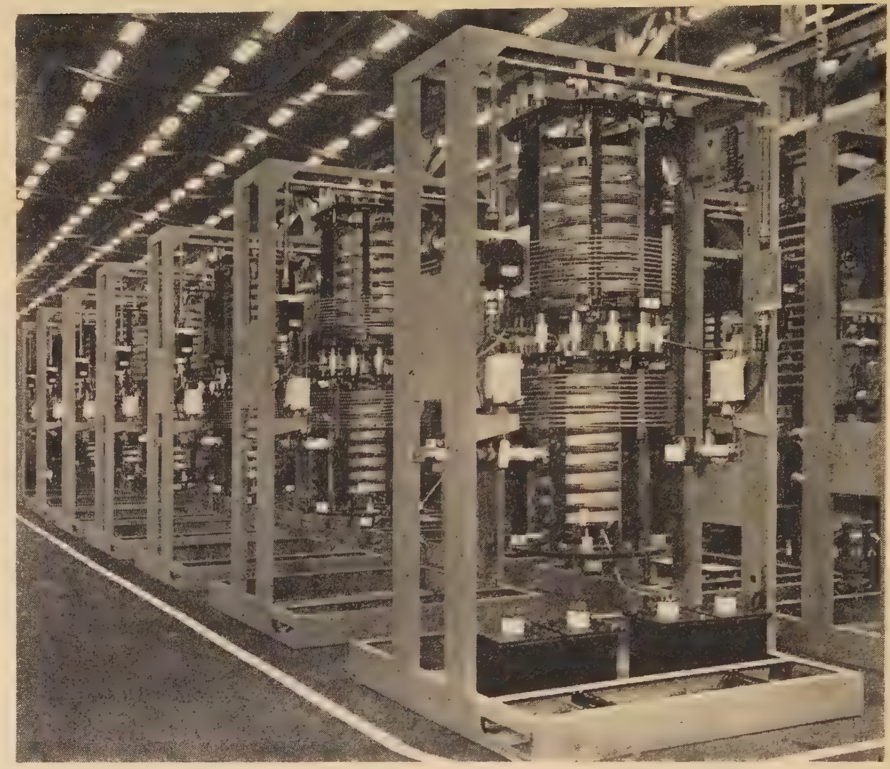
Brazil's Manufacture of Electric Motors Stimulated by War

The manufacture of polyphase electric motors in Brazil has made notable progress since the outbreak of the war, *Foreign Commerce Weekly* recently reported. Five companies in Sao Paulo are now making motors of this type to take the place of those formerly supplied by Germany, Italy, and Belgium.

In 1940, the Sao Paulo plants produced 3,393 motors valued at about $101,000; in 1942, their output increased to 24,629 motors valued at approximately $923,100. This is said to be sufficient to meet most domestic requirements, except for large units.

So far as is known, single-phase motors are not now being manufactured in Brazil. It is reported, however, that at least one company is interested in entering that field.

1,400 Kw for Electronic Tin Fusing



Electron-tube oscillators supply energy at 200,000 cycles per second to the induction heating coils that flow electrolytically deposited tin plate on steel strip into a smooth shiny surface. Shown here are seven oscillator tank circuits for 200-kw units being assembled at the radio division of the Westinghouse Electric and Manufacturing Company, Baltimore, Md.

Welding Library Established at Ohio State University

A new welding library, known as the A. F. Davis Welding Library, has been established at Ohio State University, according to E. N. Manchester, university librarian. It is the gift of A. F. Davis, vice-president and secretary, The Lincoln Electric Company, Cleveland, Ohio. Located in the Industrial Engineering Building, the library is under the supervision of J. R. Stitt, associate professor of engineering at the university. Though in its early stage of development, the collection already numbers over 700 volumes. A part of the library will be set aside for filing papers contributed by engineers representing original work in welding engineering.

Foreign Patent Applications Published. Annotated lists arranged by classes of patent applications formerly vested in enemy and enemy-occupied countries are being published in the weekly *Gazette* of the United States Patent Office. Part of the list of more than 3,000 applications will be published each week, according to the Office of the Alien Property Custodian in whom the patents are vested. However, a few applications of special military importance are being withheld from publication. For a more detailed account of the patent applications and the patents which have been vested from the enemy see *Electrical Engineering*, June 1943, page 277.

OTHER SOCIETIES •

Industrial Research Institute Holds Annual Meeting

A comparison of present and probable future research organization in Great Britain and the United States was the topic of discussion at the general dinner session of the fifth annual meeting of the Industrial Research Institute held recently in New York, N. Y.

In bringing out the differences between the two countries, the proportionately larger amount of British government and trade association research activity because of the slower adoption of research by industry was emphasized by G. S. Whitby, formerly director, Chemical Research Laboratory, department of scientific and industrial research, Teddington, England. However, Doctor Whitby was hopeful that the present general recognition, in England, of the importance of postwar planning would lead to an increase in technical research. The preponderant place which American industrial research laboratories have taken in contributing to the increasing military superiority of the United Nations was pointed out by R. W. King (M '35) assistant vice-president, American Telephone and Telegraph Company, New York, N. Y. In his opinion, the impetus which the war has given to research may be accompanied by rising costs which will place such activity beyond the resources of private industry.

Sessions on new research tools, research management problems, co-operative intra-industry research, and the rating of research personnel were also attended by the 70 industrial executives and research directors who represented the 55 member companies of the Institute, during the two-day meeting.

New officers elected for the year 1943–44 were: *Chairman* of the executive committee, W. R. Hainsworth, vice-president, Servel, Inc., New York, N. Y.; *vice-chairman*, H. K. Work, manager of research and development division, general metallurgical department, Jones and Laughlin Steel Corporation, Pittsburgh, Pa. Committee members elected for three-year terms were: A. G. Ashcroft, product engineer, Alexander Smith and Sons Carpet Company, Yonkers, N. Y.; T. K. Cornwell, director of research, Sylvania Industrial Corporation, Fredericksburg, Va.; J. M. McIlvain, administrative supervisor, research and development, Atlantic Refining Company, Philadelphia, Pa.

ASA Compiles Standard on Electrical Symbols

Based on the principle of providing a fundamental symbol for each component part of an electric device, an, "American Standard Graphical Symbols for Power, Control, and Measurement," has been issued by the American Standard Association.

This standard is an attempt to obtain national acceptance of symbol and wiring-diagram standardization. From the fundamentals included in the standard, symbols for any complete electric device or unit of equipment can be prepared. The resulting standardized diagrams then can be understood readily and followed easily during wiring. Preference has been given to symbols which are simple in design and easy to understand and reproduce and are widespread in use and application. The drafting time required to draw them and the over-all appearance were both considered. Included in the standard are: elementary control wiring diagrams, controller wiring diagrams, external controller wiring diagrams, controller construction diagrams, and control sequence tables. As the ASA has presented them, the symbols are not all rigidly defined. It has been left to commercial usage to iron out differences of opinion about the best symbol in some instances. In such cases alternate symbols are given.

Copies of the standard may be procured from ASA headquarters, 29 West 39 Street, New York 18, N. Y.

Future Meetings of Other Societies

American Chemical Society. September 6–10, 1943, Minneapolis, Minn.

American Institute of Mining and Metallurgical Engineers. Joint fuels conference, October 28–29, 1943, Pittsburgh, Pa.

American Society for Metals. Annual convention, October 18–22, 1943, Chicago, Ill.

American Society of Mechanical Engineers. Annual Meeting, November 29–December 3, 1943, New York, N. Y.

American Society for Testing Materials. Annual meeting, June 28–July 2, 1943, Pittsburgh, Pa.

National Safety Congress and Exposition, October 5–7, 1943, Chicago, Ill.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Commutation in A-C Motors

To the Editor:

Some 40 years ago the theory of commutation was studied mathematically by Girault, Arnold and Mie, Pichelmayer, Rothert, Arnold, Rüdenberg, Ossanna, T. Reid, A. Press, and others, who set up fundamental differential equations and solved them either graphically or under certain simplifying assumptions for the d-c case, with a brush covering one segment or less.

In some cases, as in the article by Press in *Electrical World* December 16, 1905, the investigation was limited to the conditions existing at the last moment of short circuit in d-c machines which avoided the integration and yet gave a good picture of the phenomena. This analysis is feasible only if the brush covers one segment or less. No similar analysis for the a-c case seems to have been given. Such an analysis follows:

In reference to Figures 1 and 2, with armature at rest, the potential difference between segment 1 and brush b is

$$I_c[2(R+r)+w]+jI_c(\pm e_T\pm\omega L) \qquad (3)$$

since ωL is small relatively to e_T, it can be neglected, and we can write for the absolute value

$$I_c\sqrt{[2(R+r)+w]^2+e_T^2}<5 \text{ to } 7 \text{ volts} \qquad (4)$$

Here and below this is of course not the whole story. Other aspects are the rate of energy dissipation per unit of contact area, or volume, and its duration. Also local short-circuit current. The instantaneous value of current in a path, $I=I_m\sin(\omega t+\theta)$, where I_m is the crest value of the current per armature path, and θ is the point in the cycle at which commutation begins. With the armature in motion the differential equation of commutation may be set up as follows:

For any coil in Figure 1, the electromotive forces or drops in the local circuit b-1-coil-2-b and their directions are

Contact drop between 2 and $b=$

$$\frac{I_m\sin(\omega t+\theta)-i}{T-t}RT \text{ (counterclockwise)}$$

Resistance drop in lead to $2=$

$$[I_m\sin(\omega t+\theta)-i]r \text{ (counterclockwise)}$$

Resistance drop in coil $=iw$ (clockwise)

Self-inductive drop in coil $=L\frac{di}{dt}$ (clockwise)

Speed electromotive force in coil $=$

$$I_me_s\sin(\omega t+\theta) \text{ (clockwise)}$$

Transformer electromotive force in coil $=$

$$I_me_T\cos(\omega t+\theta) \text{ (counterclockwise)}$$

Commutation poles will reduce e_s and e_T or even make them negative.

Contact drop between 1 and $b=$

$$[I_m\sin(\omega t+\theta)+i]\frac{RT}{t} \text{ (clockwise)}$$

Resistance drop in lead to $1=$

$$[I_m\sin(\omega t+\theta)+i]r \text{ (clockwise)}$$

$e_s=$ speed electromotive force in short-circuited coil when $I_m=$ one ampere per path

$e_T=$ transformer electromotive force in short-circuited coil when $I_m=$ one ampere per path

Combining terms gives the Kirchhoff law equation

$$\frac{I_m\sin(\omega t+\theta)-i}{T-t}RT+[I_m\sin(\omega t+\theta)-i]r+$$

$$I_me_T\cos(\omega t+\theta)=iw+L\frac{di}{dt}+I_me_s\sin(\omega t+\theta)+$$

$$[I_m\sin(\omega t+\theta)+i]\left(\frac{RT}{t}+r\right) \qquad (5)$$

If it were not for the difficulty and complication, this equation would be integrated to give $i=f(t)$, thence $L(di/dt)$, contact drops and current densities, all as functions of time, particularly at the last instant when $t=T$. For this last part, the result may be obtained without integration by the following expedient:

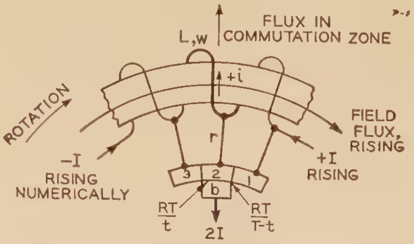


Figure 1

At the limit, where i approaches $+I_m\sin(\omega t+\theta)$ and t approaches T, the first term takes the form 0/0. This may be evaluated by taking the derivatives of numerator and denominator, whence at $t=T$

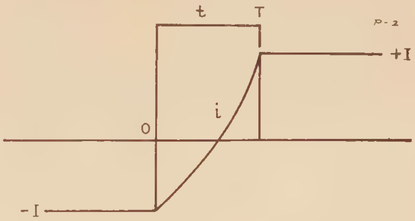


Figure 2

$$\frac{\omega I_m\cos(\omega t+\theta)-\left(\frac{di}{dt}\right)_{T=}}{-1}\cdot RT$$

with this, equation 5 becomes the algebraic expression

$$\frac{\omega i_m\cos(\omega T+\theta)-\frac{di}{dT}}{-1}\cdot RT+0+I_me_T\times$$

$$\cos(\omega T+\theta)=I_m\omega\sin(\omega T+\theta)+L\frac{di}{dT}+$$

$$I_me_s\sin(\omega T+\theta)+2(R+r)I_m\sin(\omega T+\theta) \qquad (6)$$

This gives for the derivative at the last moment

$$\frac{di}{dT}=\frac{I_m\{(\omega RT-e_T)\cos(\omega T+\theta)+[2(R+r)+w+e_s]\sin(\omega T+\theta)\}}{RT-L} \tag{7}$$

or when converting to effective values

$$\left(\frac{di}{dT}\right)_{\text{eff}}=\frac{I_{\text{eff}}}{RT-L}\times\sqrt{[2(R+r)+w+e_s]^2+(\pm\omega RT\pm e_T)^2} \tag{8}$$

At the moment of separation, the electromotive force between, 2 and b

$$e_{\text{spark}}=L\frac{di}{dT}+I_m[2(R+r)+w+e_s]\times\sin(\omega T+\theta)-I_me_T\cos(\omega T+\theta) \tag{9}$$

of which the effective value is

$$(e_{\text{spark}})_{\text{eff}}\cong\frac{RT/L}{RT/L-1}\times\sqrt{[2(R+r)+w+e_s]^2+e_T{}^2} \tag{10}$$

If the armature is at rest, $T=\infty$, and this becomes equal to equation 4. The terms in equation 10 which contains RT/L represent the effect of motion and coil inductance.

Limitations. This derivation neglects effect of nonparallel edges, current and current-density effects, time element in arc and spark phenomena, glowing, ionization, and vapor effects (when sparking occurs, the given differential equation represents the action less accurately), nonconstancy of R, nonconstancy of L (which becomes lower as di/dt increases, because of eddy currents in core iron, etc.), effect of shunt path through rest of armature, saturation, effect of commutator-bar insulation, inequalities of construction, and vibration.

Example. To illustrate the application of the preceding formulas, consider the following values:

$I_{\text{eff}}=10$ amperes per path
$r\cong 0$ ohm
$R=0.1$ ohm
$w=0.002$ ohm
$e_s=0.2$ volt per ampere of I_m
$e_T=0.4$ volt per ampere of I_m
Brush, 0.2 inch by 1.0 inch, $a=0.2$ square inch
Average effective current density $=100$ amperes per square inch
Effective current per brush $=20$ amperes
$L=0.00005$ henry
$T=0.001$ second
$\omega=377$ radians per second (60 cycles)
$\omega L=377\times 0.00005=0.0188$ ohm
$2I_{\text{eff}}R=2\times 10\times 0.1=2$ volts $=$ drop at one brush
$RT=0.1\times 0.001=0.0001$
$I_{\text{eff}}w=10\times 0.002=0.02$ volt

$$\begin{cases}\left(\dfrac{di}{dt}\right)_{\text{avg}}=\dfrac{2I}{T}=\dfrac{2\times 10}{0.001}=20{,}000 \text{ amperes per second}\\[2ex] L\left(\dfrac{di}{dt}\right)_{\text{avg}}=0.00005\times 20{,}000=1 \text{ volt}\end{cases}$$

At last moment, for direct current,

$$\begin{cases}\dfrac{di}{dT}=\dfrac{10}{0.00005}[2\times(0.1+0)+0.002+0.2]=80{,}400 \text{ amperes per second}\\[2ex] (E_{\text{spark}})_{t=T}=I\left(1+\dfrac{L}{RT-L}\right)[2(R+r)+w+e_s]\\[2ex] \qquad=10\left(1+\dfrac{0.00005}{0.0001-0.00005}\right)[2\times(0.1+0)+0.002+0.2]=8.04 \text{ volts}\end{cases}$$

For alternating current,

$$\begin{cases}(E_{\text{spark}})_{t=T}=10\sqrt{\left(1+\dfrac{0.00005}{0.0001-0.00005}\right)^2[2\times(0.1+0)+0.002+0.2]^2+\left[\left(1+\dfrac{0.00005}{0.0001-0.00005}\right)\times 0.4+\dfrac{377\times 0.00005\times 0.0001}{0.0001-0.00005}\right]^2}\\[2ex] \qquad=10\sqrt{2^2\times 0.402^2+(0.8+0.0377)^2}=11.6 \text{ volts}\end{cases}$$

$$\text{The current density}=\frac{\text{current}}{\text{area}}$$

$$=\frac{I_m\sin(\omega t+\theta)-i}{\alpha\dfrac{T-t}{t}}$$

$$=\frac{T}{\alpha}\,\frac{\omega I_m\cos(\omega t+\theta)-\dfrac{di}{dt}}{-1} \tag{11}$$

and

the watts per square inch of contact area $=$ (density) $\times$ (R per square inch)

Then for direct current,

$$\left.\begin{array}{l}\text{Density}=\dfrac{T}{\alpha}\dfrac{di}{dt}=\dfrac{0.001}{0.2}\times 80{,}400\\ \quad=402 \text{ amperes per square inch}\\ \text{Watts per square inch}=402^2\times 0.02=3{,}236\\ \text{Watts per brush}=20\times 2=40 \text{ at uniform current density or } 5\times 40=200 \text{ per square inch}\end{array}\right\} \tag{12}$$

and for alternating current

the instantaneous and effective densities at the last moment, respectively

$$=\frac{I_mT}{\alpha}\left\{\left[-\omega+\frac{(\omega RT-e_T)}{RT-L}\right]\cos(\omega t+\theta)+\frac{[2(R+r)+w+e_s]}{RT-L}\sin(\omega t+\theta)\right\} \tag{13}$$

and

$$\frac{I_{\text{eff}}T}{\alpha}\left(\frac{1}{RT-L}\right)\sqrt{[2(R+r)+w+e_s]^2+[\pm\omega L\pm e_T]^2}$$

$$=\frac{10\times 0.001}{0.2}\left(\frac{1}{0.1\times 0.001-0.00005}\right)\sqrt{[2(0.1+0)+0.002+0.2]^2+[377\times 0.00005+0.4]^2}$$

$$=580 \text{ amperes per square inch} \tag{14}$$

When Brush Covers More Than One Segment. Here a system of as many differential equations as short-circuited coils exists. Because of mathematical difficulties, neither integration nor a process similar to that already given are feasible. Because of this, resort to approximate methods and other viewpoints is necessary, and a variety is possible. A number of these was indicated. Another was given by F. W. Carter in 1909 in the form $RT/\Delta>1$, where Δ is a determinant involving the self- and mutual-inductances of the group of coils short-circuited at a brush. Numerical integration is possible but has been little used.

A. F. PUCHSTEIN (M '27)

(Electrical engineer, Jeffrey Manufacturing Company, Columbus, Ohio)

The Solution of Transient Problems

To the Editor:

There has been a great deal of controversy recently concerning the relative merits of the operational or transform methods and the classical methods of obtaining solutions of transient problems. Professor W. V. Lyon in his article "A Comparison of the Transform and Classical Methods," published in the May 1943 issue of *Electrical Engineering*, pages 198–203, discusses the amount of numerical computation required to determine the transient currents in linear lumped networks by the classical and by the transform or operational method. Professor Lyon points out that in both the classical and the transform method of solution, the characteristic equation of the system must be derived and its roots computed. This is true, and as a consequence, the amount of arithmetical labor involved in the determination of the transient behavior of circuits involving a large number of meshes is so enormous that the analysis of such circuits by these methods is practically impossible.

I wish to point out that there exists still another method which is little known or used by the electrical engineering profession but which is now quite well known and used by mechanical engineers working in the field of mechanical oscillations.

In 1934, two English investigators, W. J. Duncan and A. R. Collar published a paper,[1] that attacked the problem of solving a system of differential equations of the Lagrangian type from an entirely different point of view. In this paper, Duncan and Collar demonstrated how the transient behaviour of linear systems devoid of damping may be carried out with a minimum amount of numerical labor. By this method, the work of determining the characteristic equation is avoided, and the roots of the equation are determined by a purely matrix multiplication scheme that is ideally adapted to operations that may be performed on a modern calculating machine.

In this manner, the various characteristic values and corresponding modal columns are determined. It is then a simple matter to determine the response of the system subject to certain initial mesh charges and currents and to the application of electromotive forces in the various meshes. An electrical application and extension of the method of Duncan and Collar will be found in references 2 and 3. It may be stated that the power of the method is such that, by its use, Duncan and Collar obtain the transient behavior of undamped dynamical systems which correspond to electrical networks having as many as sixteen meshes.

In 1935, Duncan and Collar published a paper[4] extending the method to damped systems, and applied it to a damped dynamical system which corresponds to a six-mesh network. The power of these iterative methods is such that in some cases, an approximate analysis of continuous systems may be obtained by considering them as lumped systems having a relatively large number of degrees of freedom. These methods have proved invaluable in the study of mechanical oscillations, and as they become better known to the electrical profession they will no doubt prove powerful tools to be used in problems where the transform and classical methods lead to a formidable amount of numerical computation. A concise exposition of the method is given in references 2–5 and a general discussion is given in reference 6.

REFERENCES

1. A Method for the Solution of Oscillation Problems by Matrices, **W. J. Duncan, A. R. Collar.** *Philosophical Magazine*, series 7, volume 17, 1934, page 865.

2. Matrices in Engineering, **L. A. Pipes.** AIEE *Transactions*, volume 56, 1937, September section, pages 1177–90.

3. Matrix Theory of Oscillatory Networks, **L. A. Pipes.** *Journal of Applied Physics*, volume 10, number 12, December 1939, pages 849–60.

4. Matrices Applied to the Motions of Damped Systems, **W. J. Duncan, A. R. Collar.** *Philosophical Magazine*, series 7, volume 19, 1935, page 197.

5. Mathematical Methods in Engineering (book), **T. Karman, M. Biot.** McGraw-Hill Book Company, Inc., New York, N. Y., 1940. Pages 196–204.

6. Elementary Matrices (book), **R. A. Frazer, W. J. Duncan, A. R. Collar.** Cambridge, 1938. Chapter X.

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A Multiorifice Interrupter for Circuit Breakers

To the Editor:

The information furnished in the article "A Multiorifice Interrupter for High-Voltage Oil Circuit Breakers" by L. R. Ludwig and W. M. Leeds in the March 1943 issue of *Electrical Engineering*, pages 119–125, is of great interest to users of electrical equipment. The excellent performance under test of the interrupter described in the paper is indicative of considerable progress in the development of arc-interrupting devices under oil.

At the end of the paper, mention is made of the saving in critical materials made possible by the use of the new interrupter, in line with the war effort. This remark is undoubtedly correct, as a smaller number of interrupters will permit an appreciable reduction of the over-all dimensions and weight of the breakers.

However, I was rather disappointed to find no suggestion for the next and much more important step in that direction that should follow the development of such a compact and efficient interrupter. That is the widespread introduction on the American market of the high-voltage live-tank oil circuit breaker, in place of the unwieldy and expensive dead-tank type now in use.

This occurred in Europe several years ago, because of the need acutely felt there of using steel and oil as sparingly and efficiently as possible, and we find ourselves now in the same situation. A few figures will give an indication of the magnitude o savings of these very critical materials that could be obtained by the suggested development. The weights listed below are average values, derived from published data on the two types of oil circuit breakers by leading American and European manufacturers, respectively:

		Net Weight		Oil Content	
Voltage Rating (Kv)	Interrupting Capacity (Kva)	Dead Tank (Pounds)	Live Tank (Pounds)	Dead Tank (Gallons)	Live Tank (Gallons)
69	1,000,000	12,500	8,000	925	60
115	1,500,000	22,500	12,000	3,000	150
230	2,500,000	77,500	21,000	16,500	300

The comparison of net weights (oil not included) is even more favorable to the live-tank type than shown by the bare figures, because a major percentage of its weight consists of porcelain, which is not a critical material. No further comment seems necessary to stress the importance that the change to this design of high-voltage oil circuit breaker would have in connection with the war effort.

Looking to the future return to normal conditions, it is certain that the reduction of oil to a negligible volume would be particularly welcome to all users of high-voltage oil circuit breakers. The simplicity of construction of the live-tank breaker may make it preferable to the compressed-air type in this range of voltage.

From the manufacturers' point of view, it would seem desirable to make the best use of the invaluable experience and knowledge accumulated on arc-interrupting devices under oil, by bringing into existence a modern type of oil circuit breaker susceptible of being accepted for many years to come.

MARIO MORTARA

(Consulting engineer, Baltimore, Md.)

NEW BOOKS • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

Applied Electronics. (Principles of Electrical Engineering Series.) By members of the staff of the department of electrical engineering, Massachusetts Institute of Technology (a publication of the Technology Press). John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1943. 772 pages, illustrations, etc., $9^{1}/_{2}$ by 6 inches, cloth, $6.50. (ESL.)

The volume presents a first basic course in electronics, electron tubes, and associated circuits prepared for use at the Massachusetts Institute of Technology. The physical phenomena involved in this apparatus are discussed. The way in which these phenomena combine to cover the characteristics and limitations of electronic devices is explained, and the applications common to the several branches of electrical engineering are described. There is a bibliography. The text provides a good background for specialized study in the fields of power, communications, measurement, or control.

Magnetic Circuits and Transformers. (Principles of Electrical Engineering Series.) By members of the staff of the department of electrical engineering, Massachusetts Institute of Technology. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1943. 718 pages, illustrations, etc., $9^{1}/_{2}$ by 6 inches, cloth, $6.50. (ESL.)

This is the second volume of the series of texts on the principles of electrical engineering prepared by the MIT staff to provide a basic course for all students of that subject. Fundamental principles are stressed, and problems of both power and communication are considered. The book is in two sections. The first discusses the current theory of ferromagnetism, the computation of the behavior of magnetic circuits, and the theory and design of iron-core reactors. The second discusses the general design of all electrical apparatus and applies the general principles to transformers.

High-Frequency Thermionic Tubes. By A. F. Harvey, with a foreword by E. B. Moullin. John Wiley and Sons, New York, N. Y., 1943. 235 pages, illustrations, etc., 9 by $5^1/_2$ inches, cloth, \$3. (ESL.)

The increasing use of very high-frequency electric energy in radio, television, and other fields has called for accurate knowledge of the properties and behavior of vacuum tubes in high-frequency apparatus. The present book treats of these properties and their relation to those of the associated electric circuits. Starting with an account of the properties of vacuum tubes at low frequencies, it then considers the changes that occur at very high frequencies. A chapter on retarding field generators follows. Two chapters are devoted to the magnetron. The final chapter describes the klystron and other special high-frequency tubes and their circuits.

American Society for Testing Materials, 1942 Book of ASTM Standards, including Tentative Standards (a triennial publication). 3 volumes, Part I, Metals, 1,643 pp.; Part II, Nonmetallic Materials, Constructional, 1,482 pages; Part III, Nonmetallic Materials, General, 1,637 pages. American Society for Testing Materials, Philadelphia, Pa., 1943. Illustrations, diagrams, etc., $9^1/_2$ by 6 inches, cloth, \$27 (3 parts); \$9 (1 part). (ESL.)

This edition, the first in three years, contains the standards, adopted and tentative, as of the present date. Emergency standards and alternate provisions issued to expedite procurement or conservation of materials are also included. The work appears in three volumes: Metals; Nonmetallic Structural Materials; Nonmetallic Materials in General. Each can be bought separately.

Micromeritics. By J. M. DallaValle. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1943. 428 pages, diagrams, etc., $9^1/_2$ by 6 inches, cloth, \$8.50. (ESL.)

This work is intended as a general guide to the behavior and characteristics of fine particles, and thus treats a subject of interest to workers in many fields of science and engineering. Methods of particle measurement, size distribution, and packing arrangements are considered, and a general theory concerning the physical properties of fine particles is presented. Industrial applications of the subject matter, as in the transportation of fine materials, in fine grinding and the treatment of dust and smoke, are discussed. There is an extensive bibliography.

Copper and Copper Base Alloys. By R. A. Wilkins and E. S. Bunn. McGraw-Hill Book Company, New York, N. Y. and London, England, 1943. 355 pages, illustrations, etc., $11^1/_2$ by $8^1/_2$ inches, cloth, \$5. (ESL.)

This collection of data on the properties of copper and its alloys will be of great value to users of the metal. The information, chiefly presented in tables and graphs, covers the physical and mechanical properties of all the alloys in commercial use. It includes the mechanical properties at low temperatures, resistance to fatigue and corrosion fatigue, and the bending properties. Much of the information is based on tests conducted under the direction of the authors. There is an excellent bibliography.

English for Engineers. By S. A. Harbarger, A. B. Whitmer, and R. Price, 4th edition. McGraw-Hill Book Company. New York, N. Y., and London, England, 1943. 225 pages, $8^1/_2$ by $5^1/_2$ inches, cloth, \$1.75. (ESL.)

This well-known guide to the study of English for engineers emphasizes the point of view of previous editions. The aim is to guide the student in his study of English and to point out the ways in which he can apply the basic principles of writing to his own activities. Part one of the book provides material for an inventory of the skills used in writing and speaking. Part two illustrates the use of these principles in the writing of letters, reports, professional papers, etc. The new edition has been skilfully revised and greatly improved.

Metallurgical Problems. By A. Butts. 2 editions. McGraw-Hill Book Company, New York, N. Y., and London, England, 1943. 446 pages, illustrations, etc., $9^1/_2$ by 6 inches, fabrikoid, \$4. (ESL.)

This is the second edition of a work published in 1932 with the title, "A Textbook of Metallurgical Problems." The purpose is to provide practical training in the calculations required in metallurgy, in such operations as the smelting of ores, drying, roasting, and calcining, in coke making and in electrolytic and hydrometallurgical processes. The new edition has been carefully revised. The data and the metallurgical processes have been brought up to date and new problems introduced.

Industrial Production Illustration. By R. P. Hoelscher, C. H. Springer, and R. F. Pohle. McGraw-Hill Book Company, New York, N. Y., and London, England, 1943. 172 pages, illustrations, etc., 11 by 9 inches, stiff paper, spiral loose-leaf binding, \$3.50. (ESL.)

The purpose of this text is to present a thorough, comprehensive, theoretical treatment of pictorial drawing, together with practical advice on its uses. Lettering, orthographic projection and sketching, axonometric projection and sketching, oblique projection and sketching, perspective, engineering delineation, and shading are discussed, with special reference to the needs of those engaged in the machine, aircraft, and shipbuilding industries.

Modern Marine Engineer's Manual, volume 2, edited by A. Osbourne and others. Cornell Maritime Press, New York, N. Y., 1943. 1,200 pages, illustrations, etc., $7^1/_2$ by 5 inches, fabrikoid, \$4. (ESL.)

The second and final volume of this work is, like the first, prepared by a number of specialists. It concludes the study of engines by a section on marine Diesel engines. Other sections deal with marine refrigeration, heating, ventilation, insulation, steering gear, deck machinery, electricity, instruments, propellers, tests, and trials. A collection of useful tables is given. The book is a practical guide for the operation and maintenance of ship machinery.

Electromagnetic Waves. By S. A. Schelkunoff. D. Van Nostrand Company, New York, N. Y., 1943. 530 pages, diagrams, etc., $9^1/_2$ by 6 inches, cloth, \$7.50. (ESL.)

This course in the theory of electromagnetic-wave transmission is based on a course given at Brown University and is the outgrowth of the author's work in Bell Telephone Laboratories, New York, N. Y. It aims to provide a course for students of communication engineering and microwave transmission and of radio engineering which will supply basic information on radiation, wave propagation, wave guides, and resonators. It will also be useful as a reference work for research workers.

Physics and Philosophy. By J. Jeans. Macmillan Company, New York, N. Y.; The University Press, Cambridge, England, 1943. 222 pages, diagrams, 9 by $5^1/_2$ inches, cloth, \$2.75. (ESL.)

The revolution in physics which has taken place in recent years has not only changed our views of that science. It has also affected the scientific basis of philosophy and thereby our general view of the world. In this interesting volume, the author traces the progress of philosophic thought through the ages and of physics since the time of Newton and shows how modern theories of physics affect our thinking on religion, on free will, and on the nature of man.

Vector and Tensor Analysis. By H. V. Craig. McGraw-Hill Book Company, New York, N. Y., and London, England, 1943. 434 pages, diagrams, etc., 9 by 6 inches, cloth, \$3.50. (ESL.)

This text is intended primarily for those who use vector and tensor analysis as a tool. For them it provides a fairly rigorous course which does not call for a thorough knowledge of modern advanced calculus, but only for acquaintance with the standard first course in the subject. The book opens with a section that supplies the necessary mathematical background. This is followed by a section on elementary vector analysis, and one on tensors and extensors. The final section considers some applications to classical dynamics and to relativity.

Calculus Made Easy. By S. P. Thompson. 2nd edition. Macmillan Company, New York, N. Y., 1943. 301 pages, diagrams, etc., 7 by $4^1/_2$ inches, cloth, \$2. (ESL.)

This little textbook, offered as "a very simplest introduction to those beautiful methods of reckoning which are generally called by the terrifying names of the differential calculus and the integral calculus," first appeared, anonymously, in 1910. In 1914 an enlarged edition appeared under the author's name. This edition is now reprinted. In vigorous colloquial style it presents the fundamentals of the calculus for the benefit of students of engineering and science.

Applied Mathematics for Technical Students. (Rochester Technical Series.) By M. S. Corrington. Harper and Brothers, New York, N. Y., and London, England, 1943. 226 pages, diagrams, etc., 9 by $5^{1}/_{2}$ inches, cloth, $2.20, without tables; $2.80, with tables; 75 cents, tables alone. (ESL.)

Arithmetic, algebra, logarithms, and trigonometry are all included in this small volume, which is intended for trade schools, factory courses, or pre-engineering study, and is also suitable for home study. Emphasis is on the practical applications. The text is based upon careful study of the mathematics essential in modern industry.

Subatomic Physics. By H. Dingle. Ronald Press Company, New York, N. Y., 1943. 272 pages, illustrations, etc., 8 by 5 inches, cloth, $2.25. (ESL.)

As used here, subatomic physics includes those divisions of physics (light, electricity, and magnetism) in which the structure of the atom is fundamental. This text, with the companion volume on mechanical physics, presents a course in which physical principles are presented in a manner that enables their application to aeronautical and related studies to be readily understood. The book is intended especially for students preparing for the air services.

Industrial Electricity and Wiring. By J. A. Moyer and J. F. Wostrel. 3rd edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1943. 541 pages, illustrations, etc., $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, $2.75. (ESL.)

The underlying principles of electricity are outlined, and the proper methods of wiring for light and power are presented fully and clearly, for use by students and electricians. The present edition has been based on the 1940 National Electrical Code. It has also been enlarged by a chapter on fluorescent lighting and one on the prevention of radio interference.

Mathematics Dictionary. Compiled from the literature and edited by G. James with the assistance of R. C. James. The Digest Press, Van Nuys, Calif., 1943. 273 pages plus 46 pages, tables, etc., $9^{1}/_{2}$ by 6 inches, fabrikoid, $3. (ESL.)

This dictionary covers the vocabulary of mathematics from arithmetic through integral calculus. Both popular and technical definitions are frequently given, or else the definition is adapted to the mathematical maturity of the probable user. The needs of secondary schools and laymen have received special attention. The new edition has been enlarged and revised.

Diesel and Gas Engine Power Plants. By G. C. Boyer. McGraw-Hill Book Company, New York, N. Y., and London, England, 1943. 447 pages, illustrations, etc., $9^{1}/_{2}$ by 6 inches, cloth, $4. (ESL.)

A practical discussion of internal-combustion power plants, intended for designers and operators. The book is not confined to a discussion of engines, but treats the plant as an entity, and attention is given to the economic conditions, power-plant design, buildings, fuel, piping, maintenance, electric equipment, and similar subjects of prime importance.

Dictionary of Science and Technology in English—French—German—Spanish. By M. Newmark. Philosophical Library, New York, N. Y., 1943. 386 pages, tables, $9^{1}/_{2}$ by 6 inches, cloth, $6. (ESL.)

This dictionary contains a list of some 10,000 English scientific and technical terms, with their equivalents in French, German, and Spanish. French, German, and Spanish indexes make it possible to use any of these languages with English. The selection is a good one and includes many recent terms which are absent from older books.

Miscellaneous Physical Tables—Planck's Radiation Functions and Electronic Functions. Prepared by the Federal Works Agency, Work Projects Administration for the City of New York, N. Y., conducted under the sponsorship and for sale by the National Bureau of Standards, Washington, D. C., 1941. 58 pages, charts, etc., 11 by 8 inches, cloth, $1.50. (ESL.)

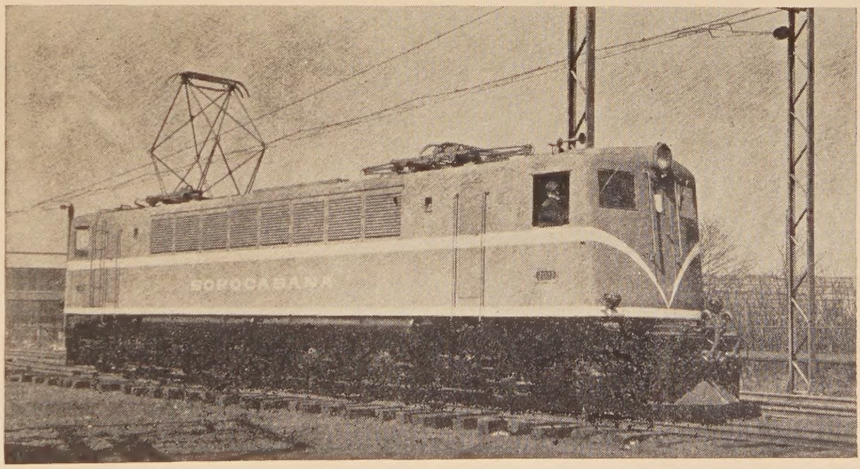
These tables give the values of Planck's radiation functions to five significant figures, and of the electronic function of six figures. The tables are the work of the WPA of New York.

Questions and Answers for Marine Engineers, Book VII—Diesel Engines—Electrical Equipment. Compiled by H. C. Dinger. Marine Engineering and Shipping Review, Simmons-Boardman Publishing Corporation, New York, N. Y., 1943. 130 pages, diagrams, tables, etc., 8 by 5 inches, paper, $1. (ESL.)

These questions and answers, compiled from "Marine Engineering and Shipping Review," cover many practical questions which have puzzled marine engineers in operating and maintaining marine Diesel engines and the electrical equipment found on small ships.

Waves and Wave Action, A bibliography of books, periodicals, and society publications appearing from 1687 through February 1943. Compiled by C. C. Lee, 1315 First North St., Vicksburg, Miss., 1942, revised 1943, typewritten, $10^{1}/_{2}$ by 8 inches, paper, $5. (ESL.)

Electrification Eases Railway Fuel Problem



This 130-metric-ton passenger and freight locomotive built by the General Electric Company is one of 20 such 3,000-volt d-c units being supplied from the United States to the Sorocabana Railway, owned by the state of Sao Paulo in Brazil, as part of its $10,000,000 electrification of 207 track-miles. These locomotives will replace 80-ton steam locomotives. Since Brazil has no important coal or petroleum resources, electrification will solve the railway's fuel problem by permitting use of hydroelectric power from the Sao Paulo Tramway Light and Power Company, according to Durval Muylaert, chief engineer, of the railway's electrification department. The railway, an essential link in Sao Paulo's foreign trade, transports much coffee, sugar, lumber, cereals, and citrus fruits eastward for export

This bibliography lists over 800 references to papers dealing with waves and wave action which appeared during the years 1687 to 1942 inclusive. The entries are arranged by authors and are, in most cases, briefly abstracted or annotated. Subject and chronological indexes are provided.

Marine Electric Power. By Q. B. Newman. 2nd edition. Simmons-Boardman Publishing Corporation, New York, N. Y., 1943. 238 pages, diagrams, etc., 8 by $4^1/_2$ inches, cloth, \$2.50. (ESL.)

This book provides a very clear explanation of the fundamental principles of electrical engineering as applied to marine electric power. Mathematics is practically absent, and only the slightest knowledge of physics is required. The new edition has been considerably enlarged by six chapters on the practical application of the principles.

National Conference on Planning, proceedings of the conference held at Indianapolis, Ind., May 25–27, 1942. American Society of Planning Officials, Chicago, Ill., 1942. 228 pages, diagrams, etc., $9^1/_2$ by 6 inches, cloth, \$2.50. (ESL.)

This book presents addresses and discussions at the conference, all of which deal with real problems of the present day. Postwar planning, the problem of converting war industries to peace uses, the man power crisis, war housing and city rebuilding after victory, state and municipal planning are discussed by experienced men.

Pre-service Course in Electricity. By W. C. Shea. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1943. 276 pages, illustrations, etc., 9 by $5^1/_2$ inches, cloth, \$2. (ESL.)

This book follows the outline of a basic course for preinduction training which has been prepared by the War Department and the Office of Education. The book covers the fundamentals of electricity, including information prerequisite to work in radio, aviation, motor mechanics, and other special subjects of military importance.

Marine Engineering. By J. M. Labberton. McGraw-Hill Book Company, New York, N. Y., and London, England, 1943. 439 pages, illustrations, etc., 9 by 6 inches, cloth, \$4. (ESL.)

This textbook is based upon courses given in the graduate division of the College of Engineering of New York University and to graduate engineers in ship and navy yards. It is intended especially for electrical and mechanical engineers who are entering this special field. Both steam and Diesel-driven ships are considered.

Essentials of Drafting. By C. L. Svensen. 3rd edition. D. Van Nostrand Company, New York, N. Y., 1943. 295 pages, illustrations, etc., 10 by 7 inches, cloth, \$2.35. (ESL.)

The basic principles of drafting and their applications are covered in this text, without unnecessary ramifications. The result is a direct treatment suited to the needs of those who make drawings and those who are to read them. The new edition has been entirely rewritten and reset in a larger format.

Boom Copper. By A. Murdoch. The Macmillan Company, New York, N. Y., 1943. 255 pages, illustrations, etc., 9 by $5^1/_2$ inches, cloth, \$3. (ESL.)

The story of the Michigan copper country, from its beginnings to the present day, is graphically told in this interesting work. The growth of the large mining interests, the men who made and managed them, how the miners lived are described in detail. In the author's words, this is "a purely informal review" that makes interesting reading.

Mechanism. By I. H. Prageman. International Textbook Company, Scranton, Pa., 1943. 296 pages, diagrams, etc., $8^1/_2$ by $5^1/_2$ inches, fabrikoid, \$3. (ESL.)

An elementary text for use by sophomore or junior students of engineering. The motions, velocities, and accelerations of various machine parts are described, as are static forces that may be transmitted in some of the simpler machines and inertia forces acting on machine parts.

The Amazing Petroleum Industry. By V. A. Kalichevsky. Reinhold Publishing Corporation, New York, N. Y., 1943. 234 pages, illustrations, etc., $7^1/_2$ by 5 inches, cloth, \$2.25. (ESL.)

This little book is a brief popular outline of the existing petroleum-manufacturing processes. What petroleum is, how it is obtained and transported, and how it is transformed into useful products are told clearly in language that laymen can understand.

Analytic Geometry. By E. S. Smith, M Salkover, and H. K. Justice. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1943. 298 pages, diagrams, etc., $9^1/_2$ by 6 inches, cloth, \$2.50. (ESL.)

A college text which aims to adjust the student to the new type of reasoning that analytic geometry calls for, by providing accurate fully illustrated explanations of the topics commonly taught in that subject.

Differential Equations. By H. W. Reddick. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1943. 245 pages, diagrams, etc., 9 by $5^1/_2$ inches, cloth, \$2.50. (ESL.)

A textbook dealing with methods of solving ordinary differential equations and with problems in applied mathematics involving them. Partial differential equations are not treated. The book is intended for both engineering and liberal arts schools.

4,000 Years of Television, the Story of Seeing at a Distance. By R. W. Hubbells G. P. Putnam's Sons, New York, N. Y. 1942. 256 pages, diagrams, $7^1/_2$ by 5 inches, cloth, \$2.25. (ESL.)

A popular account of television and its development from the earliest experiment to the present time, with a prophecy of its future.

Flight Instruments. By H. W. Hurt and C. A. Wolf. National Aeronautics Council, New York, N. Y., 1942. 92 pages, illustrations, etc., 9 by $5^1/_2$ inches, cloth, \$1. (ESL.)

This book describes the instruments in use today and shows their purposes.

Company Museums. By L. V. Coleman. American Association of Museums, Washington, D. C., 1943. 174 pages, illustrations, 6 by 9 inches, cloth, \$2.50. (ESL.)

This survey of the company museum written for business men covers descriptions of existing museums, the use of such museums, museum quarters, and the collection of suitable museum material. A distinction is drawn between the museums of industrial and related companies and those of banks and insurance companies. Eighty museums in the United States and three in Canada, belonging to industrial corporations, commercial houses, railroads, public utilities, newspapers, banks, insurance companies, and other firms, are described. The museums included are used for business reference and to further congenial public relations. They are devoted to the history, past and current, of their parent companies as well as to technical matters related to the company's business.

PAMPHLETS . . .

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Manual of Industrial Nutrition. Food Distribution Administration, Washington, D. C., 1943. 23 pages.

How to Pack Lunch Boxes for War Workers. Westinghouse Electric and Manufacturing Company, Mansfield, Ohio, 1943. 23 pages, no charge for single copies.

Allied's Radio Data Handbook. Edited by N. M. Cooke. Allied Radio Corporation, 833 Jackson Boulevard, Chicago, Ill., 1943. 48 pages, 25 cents.

Safety Speeds Production, a Message for Supervisors. Division of Labor Standards, United States Department of Labor, Washington, D. C., 1943. 21 pages.

Recent Price Interpretations Number 21. Price Legal Co-ordination Branch, Office of Price Administration, Washington, D. C., 1943. 37 pages; persons will be placed upon mailing list upon request.

A Guide to the Prevention of Weight-Lifting Injuries. Division of Labor Standards, United States Department of Labor, Washington, D. C., 1943. 19 pages.